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Semantic Processing of Nominal Metaphor: Figurative Abstraction and Embodied Simulation

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Abstract

In a metaphor such as *that lawyer is a shark*, the concept *lawyer*, which is the metaphor topic, and the concept *shark*, which is the metaphor vehicle, interact to produce a figurative meaning such that lawyers are predatory. Some theorists argue that sensorimotor properties of the vehicle are the basis of metaphor comprehension (Gibbs & Matlock, 2008; Paivio, 1979; Wilson & Gibbs, 2007). As such, *that lawyer is a shark* is processed by an embodied simulation where sensorimotor imagery associated with *sharks* is simulated (e.g., sharks hunting in deep water). However, the long-standing assumption is that metaphors are processed abstractly and sensorimotor representations play no role (e.g., Gentner & Bowdle, 2008; Glucksberg, 2008). This thesis examines the role of sensorimotor simulation in processing metaphor. In Studies 1 – 2, participants rated metaphors on comprehensibility. The metaphors contained vehicles that varied on a semantic richness variable known as body-object interaction (BOI), which characterizes the degree to which a concept is easy to interact with (Siakaluk et al., 2008). A high-BOI metaphor contains a vehicle concept that is easy-to-interact with (e.g., *life is a bicycle*) whereas a low-BOI metaphor contains a concept that is difficult-to-interact with (e.g., *life is a rainbow*). Participants rated low-BOI metaphors to be more comprehensible than high-BOI metaphors, a finding that suggests sensorimotor properties are not heavily involved in metaphor processing. In Study 3 participants created novel metaphors by pairing abstract topics with words that varied on BOI to serve as vehicles. In creating metaphors, participants chose more low-BOI words to serve as vehicles than high-BOI words. However, to interpret their created metaphors, participants used language reflective of an embodied simulation for both high and low-BOI metaphors, indicating that nominal metaphors do indeed involve sensorimotor imagery. In Studies 4 – 7,

a priming paradigm showed that processing novel metaphors (e.g., *highways are snakes*) immediately activates sensorimotor properties (e.g., slither) whereas familiar metaphors (e.g., *lawyers are sharks*) do not activate sensorimotor properties (e.g., bite) but rather, activate abstract associations (e.g., killer). In sum, the experiments in this dissertation are the first to demonstrate novel metaphors are processed by sensorimotor simulations.

Keywords

Cognitive Psychology, Metaphor Processing, Semantic Processing, Psycholinguistics, Embodied Cognition, Semantic Richness.

Co-Authorship Statement

This thesis is my own work that was supervised by Dr. Albert N. Katz. Dr. Albert N. Katz provided editorial suggestions and feedback on previous versions of this thesis.

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Table of Contents

Co-Authorship Statement.....	ii
Acknowledgments.....	iii
Table of Contents	v
List of Tables	viii
List of Figures	ix
List of Appendices	x
Chapter 1	1
General Introduction	1
The Psychological Tradition in the Study of Metaphor	3
Amodal Theories of Metaphor Processing.....	7
Research Objectives and Overview of Experiments.....	25
Chapter 2.....	28
Introduction	28
Study 1	33
Method	33
Results and Discussion.....	35
Study 2	38
Results and Discussion.....	39
General Discussion.....	44
Chapter 3	47
Introduction	47
Metaphor Production.....	49
Metaphor Interpretation	51
Study 3	57
Method	57
Results and Discussion.....	60
General Discussion.....	77

Chapter 4.....	83
Introduction	83
Embodied Simulation of Language.....	84
Embodied Simulation and Metaphor Comprehension	86
The Current Studies.....	93
Study 4	97
Method	97
Results	102
Discussion	106
Study 5	113
Method	113
Results	113
Discussion	116
Study 6	119
Results	120
Discussion	123
Study 7	124
Method	124
Results	124
Discussion	127
General Discussion.....	129
Chapter 5.....	141
General Discussion.....	141
Amodal Models	143
Embodied Models	151
Semantic Richness	159
Conclusions	163
References	164

Appendices.....	177
Curriculum Vitae	182

List of Tables

Table 1. Mean comprehension ratings broken down by topic and vehicle condition.....	40
Table 2. Percentage of items removed due to low comprehensibility ratings (< 2).	41
Table 3. Mean comprehension ratings broken down by topic and vehicle condition after the removal of anomalous items.	42
Table 4. Sample interpretations varying in embodiment for high-BOI and low-BOI metaphors. Each interpretation was provided by a different participant.	69
Table 5. Total word count and percentage of words from specific linguistic categories for high-BOI and low-BOI metaphors. <i>p</i> values are derived from independent samples <i>t</i> -tests with 1733 degrees of freedom.....	73
Table 6. Total word count and percentage of words from specific linguistic categories for high-SND and low-SND metaphors. <i>p</i> values are derived from independent samples <i>t</i> -tests with 1733 degrees of freedom.....	76
Table 7. Forward strength (FSG) between vehicle and associates, along with semantic distance to the vehicle (SD-V) and topic (SD-T) for unfamiliar and familiar metaphors. Semantic distances are determined from latent semantic analysis (LSA). <i>p</i> values reflect two-tailed <i>t</i> tests.	100
Table 8. Table 8. Percentage of errors broken down by associate type and metaphor familiarity for Study 4.....	102
Table 9. Mean reaction times and standard deviation by each condition for Study 4.	103
Table 10. Summary of theories and the downstream semantic activation they predict for familiar and unfamiliar metaphors in Study 5.	112
Table 11. Breakdown of errors by condition for Study 5.	114
Table 12. Mean reaction times and standard deviation by each condition for Study 5.	114
Table 13. Breakdown of errors by condition for Study 6.	121
Table 14. Mean reaction times and standard deviations for each condition in Study 6.	121
Table 15. Percentage of errors by condition for Study 7.	125
Table 16. Mean reaction times and standard deviations for each condition in Study 7.	125
Table 17. Overview of related cross-modal priming experiments and findings.....	133

List of Figures

Figure 1. Vehicle SND by Vehicle BOI interaction in Experiment 3. Error bars represent standard error.	62
Figure 2. Condition means in Experiment 3. Error bars represent standard error.	63
Figure 3. Histogram of Interpretations' Average Embodiment Scores.	71
Figure 4. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar metaphors in Study 4.	105
Figure 5. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar metaphors in Study 5.	116
Figure 6. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar vehicles in Study 6.	123
Figure 7. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar vehicles in Study 7.	127

List of Appendices

Appendix A. Stimuli used in Study 1	177
Appendix B. Stimuli used in Study 2.....	178
Appendix C. Stimuli used for Study 3 Topics:	179
Appendix D. Stimuli used in Studies 4 – 7	180
Appendix E Metaphors in contexts for Studies 4 and 5.....	181

Chapter 1

General Introduction

Metaphor is a conceptual and linguistic tool wherein one concept is related with another, semantically distinct concept. For example, consider the dialogue from the popular television crime-drama, *Breaking Bad*. In this scene, the main character Walter, who produces methamphetamine, tries to embolden his accomplice and distributor Jessie, who is too intimidated to sell drugs in territories controlled by gangs.

Walter: *Jessie, look at me. You are a blowfish.*

Jessie: *What?*

Walter: *A blowfish, think about it. Small in stature, not swift, not cunning; easy prey for predators, but the blowfish has a secret weapon, doesn't he? Doesn't he? What does the blowfish do Jessie? What does the blowfish do?*

Jessie [confused]: *I don't even know what a –*

Walter [moving his arms outward to mime expansion]: *The blowfish puffs up, okay, the blowfish puffs himself up four – five times larger than normal and why, why does he do that? So that it makes him intimidating, that's why. Intimidating so that the other scarier fish are scared off and that's you. You are a blowfish. You see, it's just all an illusion. It's nothing but air. Now, who messes with the blowfish, Jessie?*

Jessie: *Nobody...*

Walter: *You're damn right.*

Jessie: *I'm a blowfish...*

Walter: *You are a blowfish. Say it again.*

Jessie: *I'm a blowfish.*

Walter: *Say it like you mean it!*

Jessie [enthusiastic]: *I'm a blowfish!*

Walter: *You're a blowfish!*

This dialogue contains a perfect example of a novel metaphor; namely, that *Jessie is a blowfish*. In this case, the topic of the metaphor is *Jessie* whereas the vehicle, or the

thing that Jessie is likened to, is *blowfish*¹. In this metaphor, two nouns are juxtaposed to illustrate a semantic resemblance; as such, this metaphor is considered a *nominal* metaphor. However, metaphors take on multiple varieties; for example, metaphors can be based on adjectives, (e.g., *a seductive deal*), adverbs (e.g., *thunderous applause*), and verbs (e.g., *I killed the final exam*). Moreover, some seemingly literal language, such as (1) *he spends two hours a day exercising*, (2) *I wasted precious time*, and, (3) *you need to budget more time for your homework*, is actually metaphorical (Lakoff & Johnson, 1980). That is, according to conceptual metaphor theory, such seemingly unrelated phrases are rooted in an unconscious understanding characterized by the conceptual metaphor TIME IS MONEY (Lakoff & Johnson, 1980). According to this view, conceptual metaphors organize thought and language. Thus, many utterances reflect underlying conceptual metaphors. For example, the utterances (1) *the two went their separate ways*, (2) *we are spinning our wheels*, and (3) *they reached a dead-end street* can describe actual journeys, or, can be used to metaphorically describe relationships. As such, these utterances are rooted in the LOVE IS A JOURNEY conceptual metaphor. Therefore, metaphoric language spans multiple varieties.

Cognitive scientists interested in metaphor processing utilize different approaches for studying the metaphor varieties reviewed above. Nominal metaphors, and to a lesser

¹ The subject and predicate terms are referred to differently throughout the metaphor literature. I use the terms *topic* and *vehicle*. However, some authors use the terms *tenor* and *vehicle*. The respective terms are also referred to as the *target* and *base* in the analogy literature, or as the *target* and *source* in the cognitive linguistics literature.

extent, verb, adverb, and adjective-based metaphors, have been studied primarily within behavioural experiments in the cognitive psychology and psycholinguistics literatures. In this tradition, metaphors are assumed to be linguistic expressions that function independently from one another. On the other hand, conceptual metaphors have been mostly studied in the cognitive linguistics literature, where the primary methodology is discourse analysis. In this tradition, metaphoric utterances are assumed to be rooted in thought and not mere linguistic expressions (Lakoff, 1993). These different approaches to metaphor, which reflect different levels of analyses, have yet to be unified in a general theory. Nonetheless, in this dissertation, I adopt the tradition most studied in the cognitive psychological literature and focus on nominal metaphors. Thus the research presented here does not assume or examine so-called underlying conceptual metaphors.

The Psychological Tradition in the Study of Metaphor

Clearly, the blowfish metaphor introduced earlier is anomalous if understood literally, as is true of metaphor in general. Therefore, the broad research goal of cognitive psychologists and psycholinguists that study metaphor is to determine how the topic and vehicle interact to produce meaning. To that end, researchers have addressed two main questions: First, “*does metaphoric meaning require additional processing than literal meaning?*” And second, “*what semantic properties are involved in metaphor processing?*” Below, I review the literature that addresses these questions and argue that only the first has been satisfactorily answered whereas the second question, regarding

semantics, continues to fuel debate. Moreover, the research presented in this thesis empirically addresses the debate regarding the second question, namely the nature of the semantic properties employed in the processing of metaphor.

The Time-Course of Metaphor Processing

Perhaps the most conclusive finding since the emergence of psycholinguistic studies of metaphor is that processing metaphoric meaning occurs automatically and without additional effort than processing literal meaning (Holyoak & Stamenkovic, 2018). This has been demonstrated, for instance, by Glucksberg, Gildea and Bookin (1982). In their experiment, participants read literally-true statements (e.g., *some fruit are apples*), metaphors (e.g., *some jobs are jails*), and anomalous sentences (e.g., *some jobs are apples*) and categorized each as literally-true or literally-false while reaction times were recorded. Although both metaphors and anomalous sentences are literally-false, participants took longer to categorize the metaphors as such. This result is interpreted as an interference effect; the automatically processed metaphoric meaning must be ignored to decide the item was literally-false, which results in longer response times to metaphors than anomalous sentences, which do not automatically produce meaning. As such, this study empirically demonstrates that metaphoric meaning is computed automatically.

Since then, other studies demonstrated that metaphoric meaning is immediately processed. For instance, Blasko and Connine (1993) showed that figurative meaning for most metaphors is available as early as literal meaning. In their experiments, participants

listened to sentences that included metaphor (e.g., the belief that *hard work is a ladder* is common to this generation). At the offset of the vehicle (e.g., *ladder*), participants made lexical decisions to visually presented target words that were associated with the metaphor's figurative meaning (e.g., *advance*), literal meaning (e.g., *rungs*), or were unrelated to the metaphor (e.g., *pastry*) along with non-words. Both words related to the metaphor's figurative meaning (e.g., *advance*) and literal meaning (e.g., *rungs*) were responded to faster than unrelated words (e.g., *pastry*), suggesting that figurative and literal meaning is immediately available after one hears a metaphor.

Another study demonstrating the equivalency between metaphoric and literal processing comes from McElree and Nordlie (1999). They showed that understanding metaphors undergoes the same time-course as understanding literal sentences. Their task involved categorizing visually presented metaphors (e.g., *some mouths are sewers*), literal sentences (e.g., *some tunnels are sewers*) and anomalous sentences (e.g., *some turnips are curtains*) as comprehensible or incomprehensible. Participants were prompted to make a speeded decision to categorize the sentence when they heard a response signal presented 28 to 2800 ms after the final word of the sentence. The results showed that the rate with which metaphorical and literal sentences were correctly categorized as comprehensible was the same for both sentence types. Therefore, metaphoric and literal meaning is computed in equal time.

Taken together, the aforementioned studies empirically demonstrate that metaphors are automatically processed as such, and their meaning is immediately

available alongside literal meaning. These findings contradict the assumption that figurative meaning is processed only after a literal processing stage results in failure to interpret the metaphor (e.g., Searle, 1993). Moreover, these studies blur the distinction between metaphoric and literal processing and are consistent with computational models that assume the two processes are similar (e.g., Kintsch, 2000). However, these studies do not address how the semantic representations of the topic and vehicle interact to produce meaning. As will be reviewed below, research addressing this question has not resulted in a theoretical consensus.

Theories of Semantic Processing of Metaphor

Virtually all psychological theorists agree that metaphor comprehension is a result of an interaction between the topic and vehicle's semantic representations. Moreover, there is near unanimous agreement that processing is typically directional and entails semantic properties of the vehicle being assigned to the topic (but see Goodblatt & Glicksohn, 2017 for a special issue of papers on bidirectionality in metaphor). However, there is no agreement in regards to the particular semantic properties that underlie metaphor comprehension. For instance, in some metaphor processing theories, the assumption is that amodal properties underlie metaphor processing (e.g., Gentner & Bowdle; 2008; Glucksberg, 2008; Kintsch; 2008). By amodal, theorists are describing representations unrelated to the perceptual modality with which the concepts are experienced (i.e., a concept's sensory or motor properties). In these theories, metaphor

comprehension works by identifying conceptual information related to the vehicle and assigning it to the topic. The amodal approach can be contrasted with the embodied approach, in which sensorimotor representations of the vehicle play a critical role in metaphor processing (Paivio & Walsh, 1993; Gibbs & Matlock, 2008; Jamrozik, McQuire, Cardillo & Chatterjee, 2016)². I review the amodal and embodied theories that have been articulated to describe nominal metaphor processing next.

Amodal Theories of Metaphor Processing

Amodal theories of metaphor processing make up the bulk of the literature on the subject. In such theories, it is argued that the semantic representations of the topic and vehicle interact to identify properties that are relevant for the metaphor's meaning. Such theories are considered amodal because the properties which are relevant for metaphor comprehension are removed from sensorimotor activation. Therefore, in this approach, metaphors get their meanings from amodal semantic properties (often in the form of other words) of the topic and vehicle, rather than the bodily actions or imagery they may denote.

One major amodal approach to metaphor is based on Gentner's (1983) structure-mapping theory, which is a general theory of similarity. According to this theory, metaphors are processed by uncovering the similarity between the topic and vehicle. In

² This lack-of-consensus regarding the role embodiment plays in metaphor processing is a microcosm of the embodied cognition debate. For more on that, see the recent exchange between Glenberg and Mahon in the *Canadian Journal of Experimental Psychology*, 2015, Vol. 69 No. 2, pg. 157-181.

this framework, metaphor comprehension is the result of two processing stages. The first stage is *structural alignment*, in which the shared features between the topic and vehicle are linked. In this stage, metaphor processing is bidirectional; that is, the directionality of the metaphor is ignored in order to find common attributes of the topic and vehicle. The second stage is *projection*, in which additional relations that characterize the vehicle are cast onto the topic. In this stage, the directionality of the metaphor is apparent because only vehicle-specific relations are projected to the topic. In fact, if we recall the blowfish metaphor introduced earlier, we see that Walter’s explanation reflects the processing steps of the structure-mapping model; the shared attributes between *Jessie* and *blowfish* were initially uncovered in the structural-alignment stage; namely, “*small in stature, not swift, not cunning, easy prey*, etc.” After the common structures are aligned, a vehicle-specific relation (i.e., *suddenly becomes intimidating*) is projected to the topic, *Jessie*, resulting in comprehension. Importantly, structure-mapping suggests that metaphors are primarily understood by the topic and vehicle’s relational similarity (i.e., *intimidating*) rather than their attributive similarity (i.e., *small*).³

There is considerable empirical evidence in support of the structure-mapping position. Consider one elegant study by Wolff and Gentner (2011) where they demonstrated that the bidirectional alignment stage precedes the directional projection stage. In their task, participants were presented with forward (e.g., *some suburbs are*

³ Although adults understand metaphors by relational similarity, children understand metaphors by attributive similarity because relational thought is yet to be developed – see Gentner, (1988).

parasites) and reversed (e.g., *some parasites are suburbs*) metaphors along with anomalous and literal statements for either 600 or 1600 ms. The participants' task was to quickly (within 400 ms) rate the sentences as either comprehensible or incomprehensible. When the metaphors were presented for 600 ms, the forward and reversed metaphors were rated the same in comprehensibility; at this presentation deadline, participants were insensitive to directionality. The anomalous statements were rated lower in comprehensibility than the metaphors whereas the literal statements were rated higher than metaphors, suggesting participants were still able to process meaning at this stage. Critically, when stimuli were presented for 1600 ms, the forward metaphors increased in comprehensibility ratings whereas the reversed metaphors decreased. According to Wolff and Gentner, the 600 ms presentation deadline reflected the bidirectional alignment stage. During that stage, forward and reversed metaphors are equally comprehensible. However, the later projection stage is evident by 1600 ms; during which, metaphor directionality matters and only forward metaphors are comprehensible. Numerous other studies demonstrate additional empirical support for predictions arising from the structure-mapping model (e.g., Gentner, 1988; Gentner & Bowdle, 2001; Wolff & Gentner, 2000).

In an alternative amodal approach, metaphor comprehension is argued to be a product of categorization rather than structure-mapping (Glucksberg, 2008). According to this view, metaphor comprehension is similar to understanding literal categorization statements such as *a robin is a bird* in which the first concept, *robin*, is understood to be a category member of the second concept, *bird*. Moreover, in this view, it is argued that in

metaphors the vehicle refers to an ad-hoc category. For example, in the blowfish metaphor, *blowfish* represents an ad-hoc category of *things which are suddenly dangerous when provoked* to which Jessie is categorized as being a member. An important feature of the categorization model is dual-reference; that is, although the vehicle may typically reference a literal blowfish that swims in the ocean, this literal representation is irrelevant for comprehending the metaphor. Rather, in metaphors, the vehicle references an ad-hoc category which suggests relevant, abstract properties, such as *suddenly dangerous* or *deadly*, which are relevant in the blowfish metaphor. Furthermore, the claim is made that in the act of metaphoric categorization the literal properties of the vehicle are inhibited for the more abstract properties which define its category. Thus, *Jessie is a blowfish* can loosely be paraphrased as *Jessie is a member of the blowfish-category of suddenly dangerous things* rather than *Jessie is like a literal blowfish*.

In categorization, effective metaphor comprehension is achieved in part by how well the vehicle exemplifies an ad-hoc category (Glucksberg, McGlone & Manfredi, 1997). Consider two words which may be used as metaphor vehicles, *shark* and *virus*. According to Glucksberg et al., (1997), these vehicles differ in ambiguity⁴; *shark* is unambiguous in its reference to a single category of *vicious predators* whereas *virus* is ambiguous because it can refer to multiple ad-hoc categories, such as *things that may get*

⁴ This is not what psycholinguists call 'lexical ambiguity' which is related to polysemy.

stronger, things that can be easily passed, things that cannot be cured, etc. Moreover, recall that in categorization, the topic is not compared to the vehicle, but is rather assigned to its category. This is achieved in part by the topic constraining which category properties are relevant (Glucksberg et al., 1997). For example, the topic *lawyer* varies on few within-category dimensions; that is, lawyers only meaningfully differ in terms of their efficacy in practicing law, rather than on their gender, height, ethnicity, etc. On the other hand, the topic *man* can differ on numerous dimensions, such as height, weight, occupation, aggressiveness, etc. Some of these dimensions may be related to an ad-hoc category exemplified by the vehicle, others not. As such, the metaphor *that lawyer is a shark* has a different meaning than *that swimmer is a shark* because each respective topic constrains different aspects of the shark category. Therefore, in the categorization model, the topic and vehicle provide different sources of information for understanding metaphors, and interact differently than suggested by structure-mapping.

Glucksberg et al. (1997) demonstrated how topic constraint and vehicle ambiguity affect metaphor processing. In their task, participants read metaphors and pushed a button when they felt they could interpret their meaning. The metaphors either had high-constraint topics (e.g., *Jealousy is an infection*) or low-constraint topics (e.g., *Her family is an anchor*), along with ambiguous (e.g., *Rumors are viruses*) or unambiguous vehicles (e.g., *Alcohol is a crutch*). Before the presentation of each metaphor, either a topic prime, vehicle prime or no prime was presented. The prediction that follows from the model is that reading the topic or vehicle prior to the metaphor should have a facilitative effect

only for metaphors that have high-constraint topics or unambiguous vehicles.

Presumably, seeing the unambiguous vehicle will provide a processing advantage because the relevant category will be identified prior to processing the metaphor. An ambiguous vehicle is not facilitative as a prime because it does not identify the relevant category. Similarly, a high-constraint topic will provide relevant dimensions that constrain category properties, and is thus an effective prime. A low-constraint topic varies on many dimensions, and as such, does not provide relevant information which will facilitate processing if presented prior to the metaphor. Glucksberg et al. (1997) found these exact results in support of the categorization model; only high-constraint topics and unambiguous vehicles prime metaphor comprehension. Moreover, they argued that structure-mapping cannot explain their findings because it predicts topic and vehicle primes (irrespective of constraint or ambiguity) should facilitate metaphor processing (e.g., Wolff & Gentner, 2000). Numerous other empirical studies are interpreted in support for the categorization model (e.g., Gernsbacher, Keysar, Robertson & Werner, 2001; McGlone & Manfredi, 2001; Glucksberg, Newsome & Goldvarg, 2001).

In recognition of the empirical support for both structure-mapping and categorization, more recent approaches have combined the two processes in single models. For example, the structure-mapping framework now includes an extension, the *career-of-metaphor* hypothesis (Bowdle & Gentner, 2005). This hypothesis states that the career, or conventionality of the metaphor, affects its processing mechanism. Novel metaphors are understood as similarity-based comparisons, whereas conventional

metaphors can be understood as categorizations, because the abstracted sense of the vehicle becomes more apparent after repetitive use. On the other hand, the categorization framework now includes *the quality-of-metaphor hypothesis* (Glucksberg & Haught, 2006). In this hypothesis, metaphor quality, or aptness, determines the processing mechanism; apt metaphors are categorizations, whereas inapt, or poor quality, metaphors are similarity-based comparisons. In the literature, the structure-mapping and categorization models are considered at odds with one another. However, these models share in common the assumption that amodal properties underlie metaphor processing. The main difference between them is that in structure-mapping, figurative relations are drawn from the literal representation of the vehicle whereas, in categorization, properties are drawn from an abstraction of the vehicle.

Predication Model

The last major amodal approach articulated for nominal metaphor processing (and sentences in general) is Kintsch's (2000; 2001; 2008) predication algorithm. According to this approach, the topic and vehicle representations are not defined in terms of relations, such as in structure-mapping, or abstract categorical properties, such as in categorization. Rather, in this approach, a concept's representation is defined by its semantic neighbourhood, which is the group of words it co-occurs with in natural language. Semantic neighbourhoods are computed by co-occurrence models such as latent semantic analysis (LSA) (e.g., Landauer, Foltz & Laham, 1998 for an introduction). Latent semantic analysis models semantic memory solely from mathematically analyzing

discourse. In LSA, a word's meaning is represented in a multidimensional space as a vector and the semantic distance to other word vectors can be calculated. Semantic neighbours are therefore words that are close to each other in the space. For example, according to LSA, the semantic neighbourhood of the word *dog* is made up of the numerous words it co-occurs with, such as: *barked, dogs, wagging, collie, leash*, etc. Moreover, semantic neighbours as determined by LSA are represented as amodal units because they do not encode directly experienced sensorimotor properties (Landauer et al., 1998). Kintsch's (2000; 2001) predication algorithm uses representations determined by LSA to compute a metaphor's meaning.

To compute a metaphor's meaning, such as *my lawyer is a shark*, the algorithm first constructs a spreading activation network to search the semantic neighbourhood of the vehicle to find words that are also (though distantly) related to the topic. Because the topic and vehicle are unrelated, the search can potentially involve over one-thousand items. After finding any related words, such as *vicious*, for example, the remaining unrelated words are inhibited. A metaphor vector based on the topic, vehicle, and their shared semantic neighbours is then computed. The metaphor vector represents the meaning of the metaphor within the semantic space. The model's accuracy can be determined by comparing the resultant metaphor vector to other words which it ought to be related to. For example, Kintsch (2000) demonstrated how the predication algorithm's vector for the metaphor *my surgeon is a butcher* is close to the word *axe* while the reverse, *my butcher is a surgeon* is close to the word *scalpel*. Thus, the model produces

intuitively plausible responses. The model has also successfully simulated human interpretations to metaphors (Kintsch and Bowles, 2002). Unlike the cognitive models, such as structure-mapping or categorization, the predication model does not lead to predictions of particular semantic properties, such as relations or category properties, to be involved in metaphor. Rather, the predication model bases its computation solely on semantic neighbours, without consideration of how they are related to the vehicle (e.g., relationally or categorically).

Despite the differences between the models reviewed above, they share an important similarity: all of these models essentially argue that metaphors get their meanings from amodal associations rather than sensorimotor properties. In this thesis, I consider sensorimotor properties to be perceptual or motoric properties that relate to the topic or vehicle's literal referents. For example, recall again the metaphor *lawyers are sharks*. In this metaphor, sensorimotor properties of *sharks* may be in the form of imagery, such as sharks hunting in deep water, or the actions carried out by sharks, such as biting. Thus, sensorimotor properties are broad in the sense they are multimodal (i.e., visual, motoric, auditory, tactile, or olfactory). However, they are nonetheless sourced from the vehicle's literal representation. Note that sensorimotor properties are ignored in amodal models, where the basis of metaphor is in the form of categorical or relational associates, such as *vicious* or *preys*, respectively. The main aim of this thesis was to test whether sensorimotor properties play an important role in metaphor comprehension, as is suggested by embodied approaches to nominal metaphor.

Embodied Approaches

Although the majority of psycholinguistic evidence demonstrates support for amodal processes, recent approaches have embraced the embodied perspective to metaphor. In this newer perspective sensorimotor experience is thought to play a central role in metaphor processing. This is reflective of the general theory of embodied cognition where it is proposed that the body plays a significant role in cognitive processing (e.g., Barsalou, 1999; Lakoff, 2008; 2012; Gibbs, 2006; Wilson, 2002).

The general theory of embodied cognition can take-on multiple varieties, as outlined in a useful framework by Wilson (2002). For example, Wilson described how cognition is embodied in that 1) cognition is situated in the environment (e.g., the environmental inputs affect cognition); 2) the environment produces temporal pressure on cognition (e.g., rapid cognition for survival); 3) difficult cognitive operations can be made easier by off-loading them in the environment (e.g., solving a puzzle by trying solutions in the environment rather than mentally); 4) the cognitive system includes the environment (e.g., characterizing the mind is impossible without reference to the environment); 5) cognition is related to action (e.g., motoric properties from the environment are stored for future cognitive tasks); 6) sensorimotor experience learned from the environment may re-occur in off-line cognition (e.g., previous sensorimotor experience affects cognition in the form of embodied simulations, such as mental imagery).

In this dissertation, when referring to embodiment and nominal metaphor, I am

focusing on the 5th and 6th dimensions delineated by Wilson (2002), in which a concept is defined in part by its motoric affordances, and its sensorimotor properties may be retrieved from semantic memory during metaphor processing. In this approach to embodied cognition, it is argued that the representational system includes sensorimotor properties that one encounters in the environment. For example, when one processes the conceptual representation of a chair, one engages in an embodied simulation where sensorimotor properties that were acquired from previous interactions with chairs are partially accessed, such as their appearance, feel and the bodily positions they afford, (Barsalou, 1999). According to this view, abstract concepts are also represented by sensorimotor information. For example, part of the meaning of the abstract concept *desire* is thought to-be-represented by sensorimotor properties of *hunger*, because desire and hunger naturally co-occur (Gibbs, Lima & Francozo, 2004).

For an illustration of an embodied cognition effect, consider Hauk, Johnsrude and Pulvermüller's (2004) study, where participants passively read action words (e.g., *kick*, *pick*, *lick* etc.) in a brain-scanner. The brain regions activated in response to reading action words, overlapped with motor and premotor cortex areas that are involved with actually moving the respective body part denoted by the word, such as areas related to moving the leg, arm, or face, respectively. Such a finding is taken as evidence by embodied cognition theorists that semantic and sensorimotor processes are related. In short, embodied approaches to cognition assume that semantic processing involves the activation of sensorimotor information.

According to an embodied approach articulated for nominal metaphors, comprehension is achieved, at least partly, through simulating actions denoted by the vehicle (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007). Returning to our blowfish example above, this is partially how Walter explains the metaphor to Jessie; that is, Walter uses gestures to simulate a scene in which a blowfish expands and scares other fish away. Unlike the amodal approaches (i.e., structure-mapping, categorization or predication), the simulation model posits that running an embodied mental simulation relevant to the metaphor's meaning is crucial to comprehension. Although Walter actually simulates expansion with his arms, this model suggests that the simulation is typically mental (i.e., subconscious) rather than overt. Importantly, the simulation mechanism proposed by Gibbs and Matlock is not necessarily independent from any amodal processing; that is, simulation may run alongside creating an ad-hoc category (Gibbs & Matlock, 2008). Accordingly, although embodied simulation may not be sufficient for complete metaphor understanding, it is nonetheless a necessary component in the comprehension process. As such, Gibbs' embodied simulation theory in general is related to Lakoff's (2008; 2012) neural theory of language, in which it is argued that 'neural circuits' that process sensorimotor information are always activated during language processing (Gibbs & Colston, 2012).

Although there has yet to be a study testing if simulation is used to comprehend nominal metaphors, there is evidence demonstrating that other forms of metaphoric language is understood in part by embodied simulation. For example, Wilson and Gibbs

(2007) demonstrated that reading sentences in which a verb is used metaphorically, such as *grasp the concept*, or, *swallow your pride* are comprehended faster if participants physically or imaginatively perform those actions (i.e., grasping or swallowing) prior to reading the phrases, than if unrelated or no movement was performed. Wilson and Gibbs (2007) drew a distinction between the metaphoric phrases used in their experiments, and nominal metaphors, such as *Jessie is a blowfish*, which do not overtly reference bodily actions. However, they maintain that it is possible that nominal metaphors may be understood via embodied simulation. They state, “We suggest, nonetheless, that even some aspects of how people infer the metaphoric meanings of metaphors like ‘Lawyers are sharks’ could engage bodily simulation processes as people create imaginative scenarios in which the metaphor makes sense (e.g., lawyers are like sharks in moving quickly and aggressively toward their victims)” (pg. 729). Moreover, Gibbs and Matlock (2008) reported indirect evidence of simulation in processing nominal metaphors; in an online workshop, teachers came up with and interpreted metaphors that describe their teaching philosophies. Often times the teachers interpreted such metaphors by describing the bodily actions relevant to the metaphor. For example, the teacher who provided the metaphor *a teacher is a dolphin* interpreted it as follows, “Always wise to the hazards that may approach, but excited and enjoying life along the way. I ride the waves of the classroom, with all their ups and downs. No matter how out of control it gets I always go back for more in search of that perfect ride”. Although this is anecdotal evidence, it does suggest that there is a simulation basis for nominal metaphor understanding, at least in an

offline comprehension task. One of the questions this dissertation addresses is whether or not bodily actions do indeed play a role in both offline and online nominal-metaphor processing tasks. Approaches other than Gibbs' simulation model also consider sensorimotor representations to play important roles in metaphor comprehension; namely, dual coding theory and sensorimotor shedding theory.

Dual Coding Theory of Metaphor

Dual coding theory (DCT) is a general framework of cognition proposed by Paivio (1971; 1986; 2007). The main premise of this approach is that cognition is mediated by two distinct subsystems; namely the verbal and image systems. The verbal system processes amodal, associative, representations whereas the image system processes multimodal representations derived from sensorimotor experience. The subsystems are independent but interconnected such that activity in one system can (and often does) spread to another. According to this approach, cognition in general can be carried out with amodal representations or mental imagery, making DCT a hybrid theory⁵. The dual coding theory has been adapted for metaphor processing (Paivio 1979; Paivio & Clark, 1986; Paivio & Walsh, 1993).

⁵ Dual coding theory was first articulated (in 1971) prior to the embodied revolution and uses different terminology than more recent theories of embodied cognition. For example, in DCT, "imagery" is the terminology used to describe sensorimotor processes and representations that may be called "embodied simulation" by theorists such as Gibbs. However, Paivio (2007) himself recognized that embodied simulation is virtually the same as imagery, describing recent theories of embodiment as "...recognized generally as old wine in new bottles" (pg. 117).

Paivio and Walsh (1993) delineated how the verbal and imagery systems conjointly underlie metaphor processing. Like other models of metaphor, in the dual coding approach, the topic and vehicle play different roles in processing, with some of the vehicle's properties being assigned to the topic. However, DCT differs from previous frameworks by emphasizing the joint contributions of imagery and associative representations in finding relevant properties shared between the topic and vehicle. In this approach, the topic and vehicle retrieve different information from long-term memory; both topic and vehicles retrieve associative information, but the vehicle additionally retrieves imagery. Moreover, the topic and its amodal associates constrain the vehicle imagery such that only relevant images are retrieved and integrated into an understanding of the metaphor. Finally, according to DCT, metaphor comprehension can also occur more-so within a single system, such as finding relevant associates between the topic and vehicle, or imagery they may share. The important consideration here is that metaphor comprehension can be achieved by both verbal processes, which are amodal, and imagery processes, which are embodied and multimodal.

Although the general framework proposed in dual coding theory has been relevant for decades, receiving more support than alternative theories (see for instance McRae & Jones, 2013), its metaphor processing framework has not gained traction. In fact, to my knowledge, only one study tested some of dual coding theory's assumptions regarding metaphor processing. Paivio and Clark (1986) employed metaphors in which topics and vehicles both independently varied on imagery in a factorial manipulation. Participants

were asked to read metaphors and release a key when they formed an interpretation, which they then produced. The results showed that metaphors with high-imagery vehicles resulted in shorter reaction times to form interpretations than metaphors with low-imagery vehicles. Topic imagery had a negative effect such that high imagery-topics resulted in longer interpretation times than low-imagery topics. Moreover, participants were more likely to successfully interpret metaphors with high-imagery vehicles than those with high-imagery topics.

In another experiment, Paivio and Clark (1986) asked participants to indicate which they thought about first when interpreting a metaphor, and which was thought about more –the topic or vehicle. Participants indicated that, when forming metaphor interpretations, they thought about topics before the vehicles, but thought more about the vehicles than topics. These findings demonstrate the different effects afforded by topics and vehicles, and the role vehicle imagery plays in metaphor processing, consistent with DCT. In summary then, the dual coding theory of metaphor, like Gibbs' simulation model, places heavy emphasis on the sensorimotor representation of the vehicle. However, unlike Gibbs' simulation model, this approach does not necessitate the activation of vehicle imagery; rather, its functional architecture is flexible enough to accommodate amodal associative mechanisms for understanding some metaphors. The important point here is that DCT can support associative, imaginal, or combined processing.

Graded Embodiment and Sensorimotor Shedding

Graded embodied cognition views, such as Chaterjee's (2010), argue for amodal and sensorimotor representations underlying cognition, much like Paivio's (2007) dual coding theory. However, in graded embodiment, it is argued that additional factors influence the degree to which processing is embodied. For example, the *sensorimotor shedding* hypothesis argues that the degree to which a concept or metaphor is processed by embodied simulation is dependent on stimulus familiarity (Jamrozik, McQuire, Cardillo & Chaterjee, 2016). According to this approach, literal concepts are understood as embodied simulations; however, as concepts begin to be used in novel contexts, the sensorimotor representations are "shed" and abstracted meanings are directly processed. This sensorimotor shedding process is thought to be similar to the shift in meaning from literal to abstracted, as spelled out by the career-of-metaphor hypothesis described earlier (Jamrozik et al., 2016).

Let us consider how nominal metaphor processing is described in the sensorimotor shedding framework (see Jamrozik et al., 2016 for additional examples of conceptual processing). According to this approach, the novel metaphor *negotiation is a muscle* would draw upon sensorimotor properties of the vehicle, such as through motor imagery. However, if used repeatedly, especially in other contexts (e.g., *concentration is a muscle*, *reading is a muscle*, etc.) the vehicle representation acquires an abstracted meaning (i.e., *something that improves with practice*) and no longer draws upon sensorimotor properties. Moreover, this approach argues that metaphor is the means in

which concepts acquire abstracted meanings. The result of sensorimotor shedding is that the familiar metaphor will draw upon an abstraction whereas less familiar metaphors draw upon literal and embodied representations of the vehicle. Therefore, like DCT, sensorimotor shedding hypothesis is a hybrid model embracing both amodal and multimodal representations. However, sensorimotor shedding considers how familiarity can result in a metaphor's (and concept's) meaning change, and makes firm predictions regarding when processing is amodal or embodied. Despite making firm predictions, this framework has yet to be empirically tested a-priori.

In summary, a wide range of theories regarding the processing of A is B metaphors have accumulated. The theories are all in agreement regarding the different roles played by the topic and vehicle terms; namely, that the representation of the vehicle provides properties that are assigned to the representation of the topic. However, the theories differ in the particular roles the topic and vehicle play in determining metaphor-relevant properties, and more importantly, in the nature of the vehicle-properties. Amodal theories, such as Gentner's structure-mapping, Glucksberg's categorization model and Kintsch's predication model consider metaphor processing to be disembodied. In these approaches, sensorimotor properties of the vehicle do not play a special role in processing metaphoric meaning. In contrast, Gibbs' model proposes that, sensorimotor simulations of the vehicle play a primary role in constraining metaphoric meaning. In Paivio's model, metaphor processing typically involves vehicle imagery, along with associative information related to both topic and vehicle. Lastly, in sensorimotor shedding, embodied

representations are thought to play a major role in understanding novel metaphors, but attenuate as a metaphor becomes familiar. Therefore, the major disagreement in the theories reviewed above is the role embodiment plays in metaphor processing, with some theories predicting no role and others predicting the opposite.

Research Objectives and Overview of Experiments

As reviewed above, research on nominal metaphor processing has mostly ignored the potential role of embodiment, focusing only on amodal representations. To that end, the research objective in this dissertation is to empirically test for the possibility that embodiment plays an important role in the processing of nominal metaphors. In Chapter 2 I present a series of experiments in which participants rated metaphors for the degree of comprehensibility. As a proxy for embodiment, the metaphor vehicles differed in what is called Body-Object Interaction (BOI), namely the degree to which it is easy to physically interact with objects. From this perspective the word *bicycle* represents a high-BOI (i.e., easy to interact with) concept, whereas the word *rainbow* refers to a low-BOI (i.e., difficult to interact with) concept (Siakaluk, et al. 2008). I hypothesized that, if embodied simulation underlies metaphor comprehension, participants should find metaphors with high-BOI vehicles, such as *bicycle*, to be more comprehensible than metaphors with low-BOI vehicles such as *rainbow*. The hypothesis follows from an embodiment argument that *bicycle* should afford motoric and other sensorimotor interaction to a much greater extent than found with low-BOI concepts, such as *rainbow*. The results of the

experiments in Chapter 2 showed that contrary to an embodied cognition account, participants rated low-BOI metaphors to be more comprehensible than high-BOI metaphors.

In Chapter 3, I present an experiment where participants created metaphors and subsequently interpreted them. To create metaphors, participants were provided with abstract words to serve as topics, and concrete words to serve as vehicles. For every topic, the task of the participants was to choose a vehicle from the options provided that, in their judgement, produced an apt and comprehensible metaphor. The vehicle options differed on BOI. If embodied theories are correct, participants should prefer to complete the metaphor with high-BOI vehicles. In a second phase of this study, participants, after they had completed producing the set of metaphors, were then asked to interpret them. The interpretations were then analyzed to see if the verbal descriptions produced employed language that is consistent with an embodied simulation. The results showed that, despite choosing more low-BOI items to serve as vehicles than high-BOI items, participants generally interpreted metaphors (both low and high-BOI) using perceptual-embodied language consistent with embodied cognition.

Unlike Chapter 2 and 3 in which the experiments were based on offline tasks, in Chapter 4 I employed cross-modal priming experiments to determine when properties related to embodied simulation are available during the time-course of metaphor comprehension. Participants listened to metaphors (e.g., *lawyers are sharks*) and, after the offset of the vehicle (e.g., *sharks*), read visually presented target words. Target words

varied in their association to the vehicle; some were bodily-actions (e.g., *bite*) whereas others were general associates (e.g., *killer*). Other target words were unrelated to the vehicle (e.g., *jeans*). To determine the type of semantic information of the vehicle is available online, I determined if bodily-actions and general associates were read faster than unrelated controls. The results showed that unfamiliar metaphors activate embodied properties online; conversely, familiar metaphors activate general associates. Therefore, Chapter 4 investigated if processing a metaphor's meaning triggers embodied properties online, and, if so, the time-course of that activation.

Collectively, the studies reported in this dissertation are the first to investigate if nominal metaphors, which are the most studied metaphor variant in psycholinguistics, are understood via embodied simulation. To that end, the experimental tasks differ and emphasize metaphor comprehension, production, and interpretation, with the aim of providing converging evidence regarding the nature of embodiment of nominal metaphors using well-established psycholinguistic methodology. Details with respect to each study are provided in the following chapters.

Chapter 2

Introduction

In the previous chapter I reviewed the critical difference between amodal and embodied approaches to metaphor processing; namely, in the latter (but not former), sensorimotor properties of the vehicle are thought to play a critical role in processing. Moreover, in Gibbs' simulation model (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007), bodily-actions related to the vehicle are particularly involved in metaphor processing, even for nominal metaphors of the form A is B. Despite these claims, experimental evidence for embodied approaches to nominal metaphor processing is scarce. One reason for this is that it is particularly challenging to construct appropriate stimuli because, in nominal metaphors, vehicles typically do not overtly reference sensorimotor information. On the other hand, verb-based metaphors, such as *push the argument* overtly reference bodily-actions, making them amenable for studying embodied simulation, as Wilson and Gibbs (2007) showed.

Despite the fact nominal metaphor vehicles do not overtly denote sensorimotor properties some evidence suggests that sensorimotor representations may still be involved in metaphor processing. For example, nominal metaphors typically have concrete (and therefore imageable) vehicles rather than abstract ones and as Paivio and Clark (1986) demonstrated, metaphors with high-imagery vehicles are interpreted faster than metaphors with low-imagery vehicles. Furthermore, Katz (1989) found that when

participants are asked to choose vehicles to complete metaphor frames (e.g., *Chemistry is the _____ of sciences*), they choose concrete vehicles more than abstract ones. Taken together, these studies demonstrate that vehicles rich in sensorimotor properties are advantaged over vehicles with less sensorimotor properties, a finding which indirectly suggests a simulation mechanism may be underlying metaphor. However vehicle concreteness does not necessarily suggest sensorimotor representations are involved in metaphor processing because one cannot rule out the influence of amodal processes. For example, Katz (1992) suggested that concrete vehicles provide a processing advantage in metaphor not because of imagery, but rather because they are in a dense semantic space with many associations. Moreover, in amodal theories of metaphor, such as Glucksberg's (2008) categorization model, vehicle concreteness is not necessarily tied to imagery. Recall that in this model, a vehicle is thought to be a basic-level category member that stands in for an ad-hoc category. Therefore, it is likely that concrete vehicles (e.g., *shark*) are more unambiguous in their reference to an ad-hoc category than abstract vehicles (e.g., *virus*),⁶ As such, facilitative effects of vehicle concreteness in metaphor processing tasks are consistent with embodied approaches to metaphor, but do not rule out amodal processes.

⁶ Although Glucksberg did not suggest concreteness per se is associated with referencing ad-hoc categories, this nonetheless seems plausible given basic-level concepts are more concrete than superordinates concepts (Rosch, 1978).

In the studies reported in this chapter the vehicles employed in the nominal metaphors used as stimuli were concrete nouns. Because concreteness may not be the most appropriate variable to characterize sensorimotor representations I employed concrete concepts that differ in their association to sensorimotor properties. Specifically I examined the possibility of physically interacting with a concrete concept. For example, a cloud can be experienced only by sight whereas an apple can be felt, tasted, smelled and even heard when bit. These differences are captured in a normed variable, body-object interaction (BOI) (Bennett et al., 2011; Tillotson et al., 2008). A word such as *apple* is high-BOI whereas a word such as *cloud* is low-BOI; moreover, high-BOI words are considered semantically richer than low-BOI words, as the former refer to more properties than the latter. The common finding between high and low-BOI words is that the latter usually result in shorter response times in lexical decision and semantic categorization tasks; as such, high-BOI words are processed faster than low-BOI words (Siakaluk et al 2008). Importantly, these studies match high and low-BOI words on concreteness, imageability, subjective familiarity, and a variety of other relevant psycholinguistic variables.

The BOI effect has been teased apart by Heard, Madan, Protzner and Pexman (2018). They asked participants to rate BOI words on related variables such as *graspability*, *ease-of-pantomime*, *number of actions*, *animacy*, *size*, *danger*, and *usefulness*. In hierarchical regression analyses, Heard et al. found that the biggest predictor of BOI ratings is *graspability*, followed by *number-of-actions* and then by *ease-*

of-pantomime, along with *animacy*, which negatively predicted BOI ratings. Therefore, high-BOI concepts tend to be easier to grasp, afford more actions, are easier to pantomime, and tend to be inanimate, relative to low-BOI concepts. The logic of the studies reported in this chapter is that BOI is an appropriate variable to test Gibbs' simulation model, as Gibbs and Matlock (2008) argued that bodily-actions are critical in metaphor processing.

In the studies reported below, BOI was used for the first time in a metaphor comprehension task. Artificial metaphors were created by randomly pairing topics and vehicles, with vehicles being either high-BOI or low-BOI words. The task involved participants rating the metaphors on comprehensibility. Gibbs' simulation model, to my understanding, leads to the prediction that metaphors with high-BOI vehicles should be more comprehensible than those with low-BOI vehicles. For example, a metaphor such as *education is a ladder* has a high-BOI vehicle whereas *education is a pyramid* has a low-BOI vehicle⁷. Furthermore, the topic words were either abstract or concrete. In theories of embodied cognition, it is argued that abstract concepts are understood through sensorimotor experience (Lakoff & Johnson, 1980); if this is the case, a topic-concreteness by vehicle-BOI interaction should be obtained such that the comprehensibility ratings for metaphors with high-BOI vehicles will be higher for

⁷ BOI ratings have been collected from native speakers of English living in North America, and as such are normed on a sample similar to those tested in the current study. Moreover, the ratings are subjective and likely culturally biased. For example, someone living in Cairo may consider a pyramid to be easy to interact with.

abstract-topics than concrete-topics.

In addition to vehicle BOI level, in the studies reported below the influence of the vehicle's semantic neighbourhood was considered. Recall that a word's semantic neighbourhood is made up of other words with which it co-occurs. Semantic neighbourhoods vary, and can be described as dense or sparse, with density defined as the average distance between a word and its neighbours (Buchanan, Westbury & Burgess, 2001). Therefore, this particular definition of semantic neighbourhood density (SND) refers to how many near neighbours a word has. Words with many close semantic neighbours are in a dense neighbourhood (i.e., high-SND words) whereas words with few close semantic neighbours are in a sparse neighbourhood (i.e., low-SND words). Because SND quantifies a word's position among its associates in the semantic lexicon, I am considering it an amodal variable. Al-Azary and Buchanan (2017) found that metaphors made up of topics and vehicles from sparse semantic neighbourhoods are more comprehensible than metaphors made up of topics and vehicles from dense semantic neighbourhoods. In the studies below, SND was first held constant in order to focus solely on BOI (Study 1), and subsequently manipulated alongside BOI to examine potential interactive effects between these two semantic richness variables (Study 2).

Semantic richness refers to the multidimensional properties a concept can refer to (e.g., Pexman, Hargreaves, Siakaluk, Bodner & Pope, 2008). That is, concrete concepts, due to their high imagery, may be considered semantically richer than abstract concepts. Similarly, and in a narrower distinction, high-BOI concepts, due to their high *motor*

imagery, may be considered semantically richer than low-BOI concepts. Similarly, high-SND concepts, due to their many near associates, may be considered semantically richer than low-SND concepts. Thus, BOI is considered a dimension related to a concept's embodied representation whereas SND is considered a dimension related to a concept's amodal representation.

Study 1

Method

Participants⁸

Forty-five University of Western Ontario students enrolled in an undergraduate psychology course participated for partial course credit. Eligibility criterion was English as a native-language.

Materials

Artificial metaphors were created by randomly pairing topics with vehicles. Topics were either (30) abstract or (30) concrete nouns whereas vehicles were all concrete nouns and either (30) high or (30) low on rated BOI. Topic words were taken from a previous study on metaphor comprehension (Al-Azary & Buchanan, 2017). For the vehicles, BOI was determined using the Bennett et al. (2011) norms of multisyllabic

⁸ The participants in this dissertation are all self-identified as native speakers of English. Because I am interested in universal effects, no other demographic information, such as age or gender, will be reported.

nouns which contain values ranging from 1 – 7. Low-BOI was defined as < 3 on the scale whereas high-BOI was defined as > 5 . The orthogonal combination led to four resulting conditions: abstract topic-high BOI vehicle (e.g., *Indecision is a Hammer*); abstract topic-low BOI vehicle (e.g., *Elevation is a Grasshopper*); concrete topic -high BOI vehicle (e.g., *A Coast is a Razor*); and concrete topic-low BOI vehicle (e.g., *A Coach is an Eagle*). Fifteen metaphors were created for each condition which resulted in a total of 60 for the experiment. Moreover, vehicle-SND was held constant such that vehicles were all low-SND words (using WINDSORS; Durda & Buchanan, 2008). In the present experiment, only low-SND vehicles were used because it was previously demonstrated (i.e., Al-Azary & Buchanan, 2017) that low-SND metaphors are more comprehensible than high-SND metaphors. As such, only using low-SND vehicles ought to result in more comprehensible metaphors in the present experiment. The SND variable in the WINDSORS database ranges from zero to one, however the median is 0.36. As such, low-SND words are those with SND values below the median in the WINDSORS database.

In addition to SND, vehicles were also similar in concreteness and frequency. Concreteness was determined by consulting Brysbaert, Warriner, and Kuperman (2014) norms, in which words were rated on concreteness using 5-point rating scales (e.g., 1 being highly abstract and 5 being highly concrete and 2 – 4 serving as intermediate values). Low-BOI and high-BOI vehicles were similar on rated concreteness (i.e., 4.75 and 4.87, respectively). Frequency was determined by consulting the English Lexicon

Project (Balota et al., 2007). Low-BOI and high-BOI vehicles were also similar on printed frequency (i.e., 7.77 and 8.07 per million words, respectively). See Appendix A for stimuli.

Procedure

Participants were instructed on screen and orally that they are to rate metaphors from 1-6 on how comprehensible they seemed, with higher scores representing items that are more comprehensible. Stimuli were presented on a computer in a self-paced comprehensibility rating task. Participants first rated three practice metaphors (*Love is a journey*, *Time is money*, *Ignorance is bliss*) and the artificial metaphors followed, presented in a random order. The three practice items were all conventional metaphors in order to bias the participants to treat the experimental items metaphorically rather than semantically anomalous. Participants rated all items from each condition.

Results and Discussion

Due to the random nature of creating the metaphors, it would be likely that many might seem anomalous and hence rated fairly low in comprehensibility. Consequently, the focus is in determining relative differences between the conditions regardless of the overall comprehensibility of the statements. Data were analyzed in a 2 (abstract topic vs concrete topic) by 2 (high-BOI vehicle vs low-BOI vehicle) repeated measures ANOVA by subjects (F_1) and in a between ANOVA by items (F_2). A main-effect of concreteness was obtained such that abstract-topic metaphors ($M = 2.43$, $SE = .10$) were rated to be

more comprehensible than concrete-topic metaphors ($M = 1.98$, $SE = .10$), $F_1(1, 44) = 46.88$, $p < .001$, $\eta_p^2 = .52$, $F_2(1, 56) = 6.97$, $p = .01$, $\eta_p^2 = .11$. Moreover, main-effect of BOI was also obtained, showing that metaphors with low-BOI vehicles ($M = 2.38$, $SE = .09$) were rated as more comprehensible than metaphors with high-BOI vehicles ($M = 2.04$, $SE = .10$), $F_1(1, 44) = 67.41$, $p < .001$, $\eta_p^2 = .60$, $F_2(1, 56) = 4.06$, $p = .049$, $\eta_p^2 = .07$. Lastly, topic-concreteness did not interact with BOI (Both $F_s < 1$).

The main effect of BOI was in the opposite direction from that predicted from Gibbs' embodied simulation position. Assuming that the BOI variable is an appropriate operationalization of sensorimotor richness which is amenable to simulation, such results are inconsistent with Gibbs' simulation model. Moreover, there was no topic-concreteness by BOI interaction, which is also inconsistent with embodied simulation models where it is argued that abstract concepts are rooted in sensorimotor experience (e.g., Lakoff & Johnson, 1980). Rather, the results are more consistent with an amodal view where it is assumed that sensorimotor properties play no particular role in metaphor comprehension. A tentative interpretation suggests that the semantic representation of high-BOI items contains too many sensorimotor properties, many of which are irrelevant for any given metaphor, and therefore interfere with computing the metaphor's meaning. Al-Azary and Buchanan (2017) proposed a similar semantic richness explanation for their finding that metaphors made up of high-SND topics and vehicles were less comprehensible than those made up of low-SND topics and vehicles. That is, they argued that semantically dense concepts activate too many irrelevant properties that must be

inhibited. Similarly, Paivio and Clark (1986) found that priming the vehicle before presentation of a metaphor increases metaphor comprehension times rather than decreases them, relative to no-primers and topic-primers. They suggested that the vehicle may contain irrelevant information which actually interferes with processing when presented prior to its respective metaphor. A similar argument could explain the BOI effect observed here.

Despite the main effects reported above, the overall comprehensibility of the items was low ($M = 2.21$) ranging from 1.2 (*A Tooth is a Giraffe*) to 3.8 (*A Coach is an Eagle; Destiny is a Fire*), which is due to the random pairing of topic and vehicle, often times resulting in anomalous sentences. In the next experiment, artificial metaphors were again constructed but only three abstract metaphor topics were employed (*Love, Life* and *Time*), with any participant only rating one of these topics. Once again, the vehicles were manipulated such that they were either high or low-BOI. The logic of using only one topic is to induce participants to consider the topic in depth, increasing comprehensibility overall and possibly that the variables manipulated within the vehicle will be made more salient.

Recall the semantic richness argument that has been employed to explain the higher comprehensibility for low-SND over high-SND metaphors reported in another study (Al-Azary & Buchanan, 2017), and by extension to the higher comprehension for low-BOI metaphors here. Consequently, vehicles were also manipulated on SND resulting in four semantic conditions (i.e., high BOI-high SND; high BOI-low SND; low

BOI-high SND; low BOI-low SND) so that the semantic richness hypothesis can be tested. If the semantic richness hypothesis is correct one would expect that metaphors low SND-low BOI vehicles to be the most comprehensible.

Study 2

Method

Participants

Seventy-four University of Western Ontario undergraduate students participated for partial course credit. Twenty-four participated in the *time* condition; 25 in the *life* condition; and 25 in the *love* condition.

Materials

One-hundred eighteen multisyllabic BOI words were used as vehicles for each of the three topics. To obtain high and low cut-offs, values were arranged from low to high on BOI ratings. Then, these items were selected if they were also in the WINDSORS database containing SND values. The BOI cut-offs were the same used in Study 1 whereas the SND cut-offs were the same used by Al-Azary and Buchanan (2017) in which a median split differentiated high and low-SND words. This resulted in 118 vehicles across four conditions; 32 high BOI – high SND (e.g., *pillow camera, bicycle*); 27 high BOI – low SND (e.g., *apple, balloon, hammer*); 23 low BOI – high SND (e.g., *butterfly, mountain, submarine*); 36 low BOI – low SND (e.g., *lighting, tiger, volcano*) which were each used in the three topic sets (*Love, Life, and Time*). The four vehicle

conditions (i.e., high BOI – high SND, high BOI – low SND, low BOI – high SND and low BOI – low SND) were comparable on concreteness (i.e., 4.92, 4.87, 4.87, and 4.75 respectively) and frequency (i.e., 8.06, 7.55, 8.07, and 7.70, per million words respectively). See Appendix B for complete list of stimuli.

Procedure

The procedure of Study 1 was employed again. The only difference is that topic was a between-subject variable.

Results and Discussion

A 3 (topic word) by 2 (vehicle BOI) by 2 (vehicle SND) mixed ANOVA was conducted, with topic as the between variable. A main-effect of topic was obtained, $F(2, 71) = 4.02$, $p = .02$, $\eta_p^2 = .10$, with Tukey post-hoc tests revealing that metaphors about love were rated as more comprehensible than metaphors about life (mean difference = 0.54), $p = .018$. No other mean differences between metaphors made up of different topics reached significance. The main-effect of BOI was nonsignificant, $F(1, 71) = .00$, $p = .989$, $\eta_p^2 = 0$, as was the main-effect of SND, $F(1, 71) = 2.149$, $p = .147$, $\eta_p^2 = .029$. The BOI by SND interaction was also nonsignificant, $F(1, 71) = .615$, $p = .435$, $\eta_p^2 = .009$. Furthermore, BOI did not interact with topic, $F(2, 71) = .203$, $p = .817$, $\eta_p^2 = .006$ nor did SND, $F(2, 71) = .839$, $p = .437$, $\eta_p^2 = .023$. However, a three-way interaction, F

(2, 71) = 3.562, $p = .034$, $\eta_p^2 = .091$ was obtained. As Table 1 shows, the effects of vehicle BOI and SND varied, albeit marginally, across different topics.

Table 1. Mean comprehension ratings broken down by topic and vehicle condition.

Topic	High BOI High SND	High BOI Low SND	Low BOI High SND	Low BOI Low SND
Life	1.94	2.07	2.02	2.01
Love	2.54	2.54	2.52	2.63
Time	2.28	2.19	2.15	2.22

The argument that having people concentrate on just a single topic would lead to an increase in comprehension ratings was not observed. For instance, nearly half (48%) of all the trials consisted of ratings of 1, indicating the respective items were considered anomalous. To provide items that reflected some metaphorical understanding, all items that received a comprehensibility rating of less than 2 were removed. Across participants, this resulted in the removal of 77 of the *Life* metaphors, 56 of the *Time* metaphors, and 33 of the *Love* metaphors. As can be seen in Table 2, the pattern of items removed varied by the topic type, with *love* metaphors overall being considered as most comprehensible, with the fewest items rated less than 2.0. Moreover, more low-BOI items were removed than high-BOI items.

Table 2. Percentage of items removed due to low comprehensibility ratings (< 2).

Topic	High BOI High SND	High BOI Low SND	Low BOI High SND	Low BOI Low SND
Life	62.5%	66.67%	69.57%	63.89%
Love	18.75%	25.93%	30.43%	36.11%
Time	43.75%	40.74%	60.87%	47.22%

After the removal of poor items, a 3 (topic word) by 2 (vehicle BOI) by 2 (vehicle SND) mixed ANOVA was conducted again, with topic as the between variable⁹. A main effect of BOI was observed, $F(1, 71) = 22.055, p < .001, \eta_p^2 = .237$. Metaphors with low-BOI vehicles ($M = 2.93, SE = .10$) were rated higher in comprehensibility than those with high-BOI vehicles ($M = 2.68, SE = .10$), replicating the main effect in Study 1. However, similar to the prior analysis, a main-effect of SND was nonsignificant, $F(1, 71) = 1.447, p = .233, \eta_p^2 = .020$. Moreover, BOI did not interact with SND, $F(1, 71) = .622, p = .433, \eta_p^2 = .009$, nor did BOI interact with topic, $F(2, 71) = 1.332, p = .271, \eta_p^2 = .036$. However, SND interacted with topic, $F(2, 71) = 5.217, p = .008, \eta_p^2 = .128$. Furthermore, a reliable three-way interaction was also observed, $F(2, 71) = 4.331, p = .017, \eta_p^2 = .109$. Two-way (vehicle BOI by vehicle SND) repeated measures

⁹ I did not perform an item analysis due to the unequal and small number of items in each condition.

ANOVAs for each topic were then conducted. See Table 3 for the means of each condition.

Table 3. Mean comprehension ratings broken down by topic and vehicle condition after the removal of anomalous items.

Topic	High BOI High SND	High BOI Low SND	Low BOI High SND	Low BOI Low SND
Life	2.47	2.86	2.83	2.86
Love	2.74	2.79	2.86	3.17
Time	2.68	2.54	3.06	2.86

For the Love metaphors, a main-effect of BOI was observed, $F(1, 24) = 6.75$, $p = .016$, $\eta_p^2 = .220$, with low-BOI ($M = 3.02$, $SE = .17$) metaphors being rated as more comprehensible than high-BOI metaphors ($M = 2.77$, $SE = .17$), along with a main-effect of SND, $F(1, 24) = 12.97$, $p = .001$, $\eta_p^2 = .351$. Low-SND metaphors ($M = 2.98$, $SE = .16$) were rated more comprehensible than high-SND metaphors ($M = 2.80$, $SE = .16$). A significant interaction, $F(1, 24) = 6.56$, $p = .017$, $\eta_p^2 = .220$, revealed that low-BOI and low-SND metaphors were rated the most comprehensible than the remaining conditions, which were rated equally comprehensible (see Table 3 for means).

For the Time metaphors, the only significant effect is of BOI, $F(1, 23) = 17.954$, $p < .001$, $\eta_p^2 = .438$, with, once again, low-BOI ($M = 2.96$, $SE = .20$) metaphors rated as more comprehensible than high-BOI metaphors ($M = 2.61$, $SE = .18$). The main-effect of SND was nonsignificant, $F(1, 23) = 3.343$, $p = .081$, $\eta_p^2 = .127$ as was the BOI by SND

interaction, $F(1, 23) = .0760, p = .785, \eta_p^2 = .003$.

Lastly, for the Life metaphors, the only significant effect is an interaction, $F(1, 24) = 4.96, p = .036, \eta_p^2 = .171$, showing that high BOI – high SND metaphors were rated as the least comprehensible (see Table 3 for means). The main-effect of BOI was nonsignificant, $F(1, 24) = 2.27, p = .145, \eta_p^2 = .086$ as was the main-effect of SND, $F(1, 24) = 2.52, p = .125, \eta_p^2 = .095$.

In total, the results of Study 2 (after removal of anomalous items) either replicate the BOI main effect in Study 1, or produce interactions which demonstrate low-BOI and low SND metaphors are rated as the most comprehensible, or the converse, that high-BOI and high-SND metaphors are the least comprehensible. These findings (a) do not support the notion that high-BOI metaphors should be more understandable because of embodied simulation and (b) suggest that the low-BOI effect found in Study 1 and low-SND effects found in earlier studies (Al-Azary & Buchanan, 2017) might be due to amodal factors based on the degree of inhibition required to produce metaphoric meaning. However, the results of Study 2 are not entirely straightforward as a high number of items were removed on the basis that they were rated as very low on comprehensibility (< 2 which makes them anomalous rather than metaphoric). Moreover, more low-BOI items were removed than high-BOI items, making the obtained BOI effects inconclusive. The experiments reported here are based on artificial metaphors created by the pairings of topic and vehicle nouns and it is unclear that the findings found here would extend to natural items. In the next Chapter I employed a procedure that should permit for the

construction of more meaningful, apt metaphors while still permitting for examination of BOI, and where relevant, SND.

General Discussion

In two experiments, metaphors with low-BOI vehicles were rated as more comprehensible than high-BOI counterparts. Although preliminary, this finding runs counter to the predictions of Gibb's simulation theory (Gibbs & Matlock, 2008), if one assumes that high-BOI vehicles in metaphors are more likely to invite embodied simulation processing mechanisms than would low-BOI vehicles. As mentioned previously, this assumption is reasonable when one considers the fact that high-BOI concepts result in faster reaction times in semantic processing tasks (Siakaluk et al., 2008). Moreover, BOI was chosen as a word-level proxy for embodied accessibility specifically because it is associated with bodily-actions, which is a critical component in Gibb's model.

Other embodied theories, such as dual coding (Paivio & Walsh, 1993) and sensorimotor shedding (Jamrozik et al., 2016) do not place a heavy emphasis on bodily-actions per se. These theories are less constrained than Gibb's model and consider the vehicle's sensorimotor representations in general to be involved in metaphor comprehension. As such, the finding of higher comprehension ratings observed for low-BOI vehicles is not particularly troublesome for dual coding theory or sensorimotor shedding if one assumes that concreteness alone is a source of sensorimotor properties.

However, such theories do not address why low-BOI metaphors are easier to comprehend than high-BOI metaphors.

The tentative speculation regarding the detrimental effects of high-BOI vehicles on metaphor comprehension ratings can be related to the semantic richness hypothesis of Al-Azary and Buchanan (2017). Recall that this hypothesis states that semantic richness of vehicles results in difficulties in determining semantic properties relevant for a metaphor's meaning. Evidence for this hypothesis comes from the finding that metaphors made up with topics and vehicles with many near semantic neighbours are rated less comprehensible (in both offline and online tasks) than metaphors made up of topics and vehicles with few near semantic neighbours. Thus, the BOI main effect is similar to previously reported effects regarding SND in metaphor; namely, high-BOI concepts refer to many semantic properties that complicate finding metaphor-relevant ones. Moreover, the unrelated properties may need to be inhibited (e.g., Kintsch, 2000) or suppressed (Gernsbacher et al., 2001). Further support for the semantic richness hypothesis comes from the finding that for *Love* metaphors, the semantically poorest condition (i.e., low BOI – low SND) was rated the most comprehensible whereas for the *Life* metaphors, the semantically richest condition (high BOI – high SND) was rated the least comprehensible. Such interactions either demonstrate the facilitative effect of less-semantically rich vehicles, or the opposite, the detrimental effect of more-semantically rich vehicles.

Despite the obtained effects found in both Studies above, caution is warranted for

two main reasons. First, the items were overall rated low in comprehensibility, which in Study 2, necessitated the removal of a significant number of items for analysis.

Furthermore, a greater number of low-BOI items were removed as anomalies than were high-BOI items, perhaps skewing the observed results. Second, the assumption that low-BOI vehicles are less likely to invite embodied simulation than high-BOI vehicles needs to be clarified. Recall that all of the metaphor vehicles, including low-BOI vehicles, are nonetheless concrete and hence likely easy to image. The data presented above do not directly test whether high-BOI metaphors are indeed easier to simulate or whether both high and low-BOI items (being concrete, imageable nouns) can simulate metaphoric meaning, perhaps within non-motoric modalities. Given the overall low comprehensibility ratings found with the artificial pairing of nouns to create metaphors, the preference is to treat the data reported here as pilot attempts in order to determine if BOI results in any effects in metaphor. Chapter 3 addresses the need to test the effects of BOI on apt and natural metaphors.

Chapter 3

Introduction

The objective in this chapter is to detect influences of embodied simulation with a more sensitive test than used in Chapter Two. To that end, I asked participants to generate metaphors, which would be more apt than the artificial and randomly generated metaphors employed in the studies described in the last Chapter. Moreover, I subsequently asked participants to interpret metaphors, rather than merely rate them for comprehensibility, as done in the studies in Chapter 2.

The two tasks (metaphor production and interpretation) employed were based on the same participants and items. Participants first created metaphors and, second, subsequently interpreted them. This task closely approximates the one reviewed by Gibbs and Matlock (2008), where they cite evidence for embodied simulation in nominal metaphor understanding. Their evidence comes from an online exercise wherein teachers were asked first to create a metaphor that describes their occupation, and subsequently explain their choice. For example, one teacher created the metaphor *a teacher is a fisherman*, and explained it by writing the following: “*Standing by the river, putting the hook into the water (no barbs on the hook). Constantly guiding the rod down the river, toward the sea of self-fulfillment. There are rapids that can cause the fish to experience a sense of confusion, but the tension from the rod is a constant, guiding them toward calmer waters. This journey cannot be completed by one fisher, the rod is passed to the*

next fisher (teacher).” Gibbs and Matlock (2008) consider such an interpretation, where the interpreter describes carrying out actions in an ‘as-if’ scenario, to be consistent with their model of embodied simulation.

Although the task discussed above is interesting, the descriptive support is anecdotal and non-experimental. Moreover, because the task consisted of teachers metaphorically describing their jobs, it is not particularly surprising that they interpreted their metaphors by describing bodily-actions apparent in other roles; that is, the task itself may invite one to engage in simulation. However, if metaphor interpretation is truly driven by embodied simulation processes, as Gibbs and colleagues propose, (Wilson & Gibbs, 2007; Gibbs & Matlock, 2008), then evidence for embodied simulation should be apparent even with simple nominal metaphors, of the form A is B. Recall that the metaphors used in the last Chapter were of the form A is B, but were randomly created, and consequently, artificial. Although there were relative differences between conditions, the metaphors overall were rated low in comprehensibility. As such, their poor quality may have contributed to the low comprehensibility ratings and precluded an opportunity for participants to engage in an embodied simulation (aptness is a critical factor in metaphor understanding; see Blasko & Connine, 1993). Therefore, in the current study, only apt metaphors were used in an interpretation task.

In order to develop comprehensible metaphors, participants were asked to create metaphors they consider both apt and comprehensible. After creating a series of metaphors, participants interpreted them. The metaphor interpretations were then

analyzed for content reflective of embodied simulation. Therefore, because the current experiment involves both metaphor production and metaphor interpretation, it is an analog to the task described by Gibbs and Matlock (2008) and should be a fair test of embodied simulation.

Metaphor Production

Metaphor production remains understudied in the psycholinguistics and cognitive psychology literatures (Holyoak & Stamenkovic, 2018; Katz, 1989). However, there are a few notable studies that revealed effects relevant for the present experiment. For instance, Katz (1989) utilized a vehicle selection paradigm where participants completed metaphor frames (e.g., *Sociology is the _____ of sciences*) by choosing the single best word from a list to serve as a vehicle (e.g., *robin, hawk, USA, Switzerland*, etc.). Two primary semantic variables of the selected vehicles were analyzed; namely, the concreteness of the chosen vehicle and its semantic distance to the topic. In regard to vehicle concreteness, participants tended to choose concrete vehicles more than abstract vehicles. In regard to semantic distance, vehicles that were chosen were a moderate distance from the topic, rather than near or far. Therefore, Katz showed that a vehicle's concreteness and its position among other concepts in semantic space both play a role in producing apt metaphors.

Whereas Katz (1989) determined semantic effects of metaphor production, Chiappe and Chiappe (2007) determined the underlying cognitive mechanisms. In their

study, participants working memory capacity was measured, with a particular focus on inhibitory control, using tasks such as reverse digit span among others. Participants then received metaphor frames consisting of a topic (e.g., *Some lectures are _____*) along with a predetermined property that is to be attributed to the topic (e.g., *Boring and put you to sleep*). For each frame, participants generated a vehicle that captured the property (e.g., *sleeping pill, lullaby, etc.*). Unlike the Katz (1989) study, no vehicle word-bank was provided; as such, participants could choose any word to serve as a vehicle. Their results showed that higher working-memory and inhibitory control is correlated with producing higher quality metaphors. They interpreted these results as follows: producing an apt metaphor requires inhibition of competing vehicles and semantic properties. This is consistent with the predication algorithm (Kintsch, 2000) and the related semantic richness hypothesis (Al-Azary & Buchanan, 2017), in which metaphor processing entails inhibiting properties of the vehicle that are unrelated to the metaphor.

The metaphor production component employed here will follow from the findings of both Katz (1989) and Chiappe and Chiappe (2007). Recall that Katz demonstrated concrete vehicles are favoured over abstract vehicles in metaphor production. However, no one to date has further characterized the concreteness of vehicles on other semantic dimensions. To that end, participants will create metaphors by pairing abstract topics with concrete vehicles that vary in BOI and SND. I chose BOI to extend the effects of Experiment 1 with a different paradigm and dependent variable; recall that in the earlier studies, low-BOI metaphors were rated as more comprehensible than high-BOI

metaphors. A conceptual replication would be obtained if participants chose to create metaphors from low-BOI, rather than high-BOI vehicles. Moreover, this would suggest, once again, that participants are not engaging in an embodied simulation when processing metaphor, assuming that high-BOI vehicles are more amenable to simulation than low-BOI vehicles. In a similar vein, SND will extend previously found effects in metaphor comprehension, showing negative effects of high-SND vehicles (and topics) (Al-Azary & Buchanan, 2017) to metaphor production. Moreover, if both low-BOI and low-SND effects are obtained the semantic richness hypothesis will be supported. Alternatively, it is possible that participants will engage in embodied simulation processes such as those described by Gibbs and colleagues, and opt for high-BOI vehicles because they afford rich motor imagery. Such an effect will be supportive of the embodied simulation framework underlying metaphor processing.

Metaphor Interpretation

The second component will involve participants interpreting their created metaphors in an open-ended task. Like metaphor production, metaphor interpretation is also understudied. However, some researchers have analyzed the content of participants' metaphor interpretations for perceptual-embodied language, which is relevant for the current study. For instance, one of the most comprehensive studies on open-ended metaphor interpretations to date is Siltanen's (1986) study. In this developmental study, children and adults interpreted metaphors varying in difficulty (i.e., easy, moderate, and

difficult), and the nature of their interpretations was assessed. Interpretations were scored regarding the degree they were perceptually-based, conceptually-based, or based on a combination of the two. For example, an easy metaphor, such as *the river is a snake* may be interpreted perceptually with properties such as “*curvy*” or “*brown*”. Or a more elaborate interpretation for the same metaphor could be “*curvy evil things that kill people*”; such an interpretation includes both perceptual and conceptual properties. Siltanen found that children (6 – 8 year olds) could only comprehend easy metaphors perceptually. However, adults (19-31) could interpret easy, moderate, and difficult metaphors conceptually and perceptually, with the great majority of interpretations being purely conceptual, or a combination of the two. Purely perceptual interpretations were only observed for some (33%) of the easy metaphors, and are therefore marginal overall. Therefore, for adults, metaphor interpretations were mostly conceptual, sometimes integrated with perceptual properties. Rarely were they only perceptual.

Although Siltanen analyzed a wide variety of metaphors across development stages, it is unclear how metaphor types (other than difficulty) may have influenced interpretations. For example, her items were technically nominal, but varied from *suspicion is quicksand* to *the surf crashing on the seashore is a symphony*. Moreover, metaphors themselves occasionally involved perceptual content (e.g., *jealousy is a green-eyed monster*; *Sally’s spider web is a shimmering silver lace*, etc.) which likely biased interpretations to include perceptual features.

Fraser (1993) reported interpretations to nominal metaphors, such as *he/she is a*

woodchuck. Although his study was a pilot experiment, Fraser found that most interpretations fit into three categories; namely, *physical*, *behavioural*, and *functional*. For example, for the woodchuck metaphor, a *physical* interpretation may include words such as “*buckteeth, ugly, fat, hairy*”. A *behavioural* interpretation includes properties such as “*industrious, shy, introvert, persistent, eats continually, waddles, persistent* etc.” along with functional interpretations “*predicts spring*”. Therefore, many of the interpretations seem to include physical properties and actions related to the literal referent of the vehicle (i.e. *fat, waddles, eats*), although, some are clearly abstractions (e.g., *industrious*). Like, Siltanen’s data, Fraser’s seems to include both perceptual and conceptual properties as well. However, Fraser (1993) used only a particular type of nominal metaphors which were all about people (e.g., *he is a woodchuck*). As such, these constrained metaphors may not generalize to others. Moreover, Fraser (1993) did not report the proportions of interpretations of any given type (i.e., physical, behavioural or functional). Upon consideration of Siltanen and Fraser’s data, it seems that perceptual or embodied language may play a role in understanding some metaphors; however, it is unclear to what degree general metaphor interpretations will include perceptual-embodied language. Nonetheless, two particular models of metaphor comprehension lead to the prediction that perceptual-embodied language will underlie metaphor interpretations of the current study.

One model is Gibbs’ simulation hypothesis (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007). Recall that, in this model, metaphor understanding arises from constructing

an embodied simulation where the aspects of the metaphor are imagined. For example, recall the metaphor, *A teacher is a fisherman*, described earlier. According to Gibbs and Matlock (2008, pg. 174), "... the new category of *A teacher is a fisherman*, for example, is created and appreciated by running the simulation, or engaging in an 'as if' scenario where bodily action and its effects are critical to the metaphor's meaning." Moreover, Wilson and Gibbs (2007) describe how the metaphor, *lawyers are sharks*, may "engage bodily simulation processes as people create imaginative scenarios in which the metaphor makes sense (e.g., lawyers are like sharks in moving quickly and aggressively toward their victims)" (pg. 729). As such, bodily motion seems to play a particular role in Gibbs' conception of embodied simulation, but sensorimotor representations in general are related to this model. Therefore, Gibbs' model predicts perceptual-embodied language to be involved in metaphoric interpretations.

Another model predictive of perceptual-embodied language in metaphor interpretations is the dual coding theory of metaphor (Paivio & Clark, 1986; Paivio & Walsh, 1993). According to this model, the imagery of the vehicle, along with verbal associates of both topic and vehicle, produce metaphor comprehension and interpretation. In fact, this model places special emphasis on the concreteness of the vehicle in order to evoke imagery. Moreover, imagery involved in understanding the metaphor is not limited only for the vehicle concept in isolation; rather, the image system stores continuous imagery, synchronously available and analogous to the perceptual world. As such, imagery beyond that of the vehicle ought to play a role in metaphor understanding. As

Paivio and Walsh (1993) put it, “Think of the sun and you simultaneously think of the sky.” (pg. 322). This model considers imagery to be multimodal rather than only visual. Moreover, dual coding theory, argues that amodal associative information (stored in the verbal system separate of the image system) plays a role in forming metaphor interpretations as well. As such, this model does not predict as strongly as Gibbs’ model that metaphoric interpretation is purely rooted in perceptual-embodied representations.

Unlike Paivio’s dual coding theory and Gibbs’ simulation model, purely amodal approaches do not give any special status to perceptual-embodied language to form metaphor interpretations. Recall that in structure-mapping (Gentner, 1983) relations of the vehicle are thought to play the primary role in metaphor comprehension. However, in structure-mapping, shared attributes of the topic and vehicle (i.e., perceptual or non-perceptual features) are aligned prior to the processing of relations. Therefore, if perceptual language is involved in metaphor interpretation, it is not particularly an issue for structure-mapping; however, this model would treat perceptual language as a precursor to processing relational information, which is accordingly fundamental to metaphor understanding. According to structure-mapping theory, even a metaphor that can involve bodily-actions, such as *Socrates was a midwife* is thought to be interpreted relationally, such as, “*Socrates did not simply teach his students new ideas but rather helped them realize ideas that had been developing within them all along.* (Bowdle & Gentner, 2005; pg. 196.)”. Clearly, this interpretation makes no reference to any bodily-actions a literal midwife might perform, unlike Gibbs and Matlock’s (2008) *a teacher is a*

fisherman metaphor.

The categorization model (Glucksberg, 2008) suggests no prediction of perceptual-embodied language in metaphor interpretation. This is because, according to this model, metaphor processing does not involve the literal representation of the vehicle, but rather an abstracted sense of the vehicle (Glucksberg, 2008). Accordingly, the meaning of the metaphor, *lawyers are sharks* would be interpreted as a result of constructing an abstract category of ‘*vicious things*’. As such, the categorization model is purely associative with no consideration of imagery. Moreover, this model holds that literal properties of the vehicle are inhibited during metaphor processing. Consequently, processing literal properties of the vehicle (e.g., *swim*) prior to the processing of the metaphor (e.g., *my lawyer is a shark*), interferes with the time taken to comprehend the metaphor (McGlone & Manfredi, 2001). Therefore, this model places no role in perceptual-embodied properties of the vehicle in metaphor interpretation; if such language is obtained in metaphor interpretations, it would be a serious issue for the categorization model.

In summary, Gibbs makes a strong claim regarding the centrality of embodied cognition in metaphor interpretations; Paivio provides a hybrid model wherein both abstract associative and embodied perceptual structures are involved in metaphor processing; and finally there are a number of theories that attribute no special role to embodiment at all in the processing of metaphor (e.g., Gentner, 1983; Glucksberg, 2008; see also Kintsch, 2000).

Study 3

Participants were presented with abstract words (e.g., *secrecy*) and potential vehicles (e.g., *sword, rat, castle, cloud*, etc.). Their task was to choose a vehicle that produced a comprehensible and apt metaphor in their judgement (e.g., *secrecy is a cloud*). The topics were all abstract but differed in SND; half were high-SND and half low-SND. The vehicles were conjointly manipulated on BOI and SND like in Study 2 of Chapter 2. After creating the metaphors, participants then interpreted their meanings. Both production and interpretation tasks provided quantitatively analyzable data. The dependent variable for the metaphor production task is the frequency of vehicle choice, similar to Katz (1989). For the interpretation task, the dependent variable is the percentage of perceptual-embodied language used.

Method

Participants

Sixty people participated for \$10. Participants were recruited from poster advertisements around campus, and the summer participant research pool at Western. Participants reported being native speakers of English.

Materials

Topics

Abstract words, determined by their ratings in the Brysbaert et al. (2014) concreteness norms, were used as topics. Words were chosen from the lowest

concreteness quartile and therefore are the most abstract. Eighteen of the topics are high SND whereas 18 are low SND. Furthermore, topics were low-frequency, ranging from 1 – 40 per million words. The abstract-high SND and abstract-low SND topics did not differ significantly on abstractness, $t(34) = 1.0076$, $p = 0.3208$, or frequency, $t(34) = 0.3389$, $p = 0.74$ but of course, differed on SND, $t(34) = 9.24$, $p < .001$.

Potential Vehicles

The items chosen as potential vehicles are concrete nouns (all rated greater than 4.5 on a 5 point concreteness scale; Brysbaert et al., 2014) differing on BOI. To develop a suitable list of items, as a starting point, we rejected the use of any vehicles which were used in metaphors that were rated less than 2 in either Study 1 or 2. For example, the word *pelican* did not work in *Love is a pelican*, *Time is a pelican*, *Life is a pelican*, or *Diplomacy is a pelican*. It is likely that pelican may be an acceptable vehicle for a particular topic in an appropriate context, but we exclude its use for the current study. Moreover, vehicles with somewhat similar meanings were reduced (e.g., *lion* and *tiger*) by choosing the one which satisfied other psycholinguistic constraints imposed on the stimuli (e.g., keeping frequency and concreteness matched). Additionally, Study 1 and 2 contained only the multisyllabic BOI nouns (Bennett et al., 201). To increase the number of potential items, in the current experiment, monosyllabic nouns were included as well (Tillotson, et. al., 2008). Lastly, each list of vehicles only had two animate items, which ought to further reduce unwanted variability that can occur with studying BOI. For example, low-BOI items tend to be animate while high-BOI items tend to be inanimate

(Heard et al., 2018). The result was four conditions of vehicles, each with 12 items (i.e., high BOI-high SND; high BOI-low SND; low BOI-high SND; low BOI-low SND). See Appendix C for stimuli.

One-way ANOVAs were conducted to ensure the four vehicle conditions only differed on BOI and SND. The vehicles did not differ in concreteness, ($p = .119$); or frequency, ($p = .952$). Critically, the manipulation of BOI is significant, ($p < .001$), with Tukey-HSD tests confirming that the high-BOI items, across SND, do not significantly differ ($p = .97$) nor do the low-BOI items, across SND ($p = .75$), but the high and low-BOI items differ from one another (both p 's $< .001$). The same can be said for the SND manipulation¹⁰ ($p < .001$), with Tukey-HSD tests confirming that high-SND items do not significantly differ ($p = .99$) nor the low-SND items ($p = .90$), but the high and low-SND items do (both p 's $< .001$).

Procedure

Participants were instructed that their task was to create metaphors by choosing a vehicle which, with the presented topic, creates a comprehensible and apt metaphor. The instructions included *time is a river* and *time is a pickle* to demonstrate that not every topic-vehicle pairing is suitable. A practice trial involved the word *Time* along with the 48 vehicles. Participants were asked to choose a vehicle for the topic, and write out the

¹⁰ The term 'manipulation' is used loosely here. This is technically a quasi-experimental manipulation because the BOI and SND values are not technically manipulated with the items themselves (i.e., manipulating a word's BOI or SND level), which is not practical in psycholinguistic experiments.

entire metaphor on a provided sheet of paper. After this practice trial, the experimental trials followed. An experimental trial consisted of the presentation of a slide that included an abstract topic-word along with 48 vehicles presented below it. The order of the vehicles was pseudo-random such that each of the 36 slides contained a unique order of the vehicles. For each trial, participants were asked to choose a vehicle that, when paired with the presented topic, results in an apt and comprehensible metaphor, and subsequently wrote out the entire metaphor in the A is B format on their provided sheet in a numbered order from 1 - 36. After writing out the 36 metaphors, phase two was initiated. Participants expected this phase, but did not know it entailed writing out explanations for the metaphors. In this phase, a slide, which contained a blank text-box, prompted the participants to type a metaphor corresponding to a random number from the sheet, along with an explanation of the metaphor. Therefore, the metaphors were interpreted in a random order, independent of the order that they were produced. The study typically took less than one hour to complete.

Results and Discussion

The data from 11 participants were not included in the analysis, for the following reasons: if they did not complete the entire study, created many similes despite the instructions given, or created extended metaphors. Thus the analyses are based on 49 participants. The resulting participants created and interpreted nominal metaphors of the form A is B (although 5 of which each created a single simile - we included such participants because a single simile may not necessarily be strategic, but possibly

accidental). I will first report the results from the vehicle selection task followed by the interpretation task.

Vehicle Selection Data

A topic (high-SND vs low-SND) by vehicle BOI (high vs low) by vehicle SND (high vs low) repeated measures ANOVA was conducted on the frequency of vehicles chosen from the four semantic conditions. A main effect of BOI was obtained, $F(1, 48) = 31.297, p < .001, \eta_p^2 = .395$; participants chose low-BOI vehicles ($M = 5.08, SE = .104$) 56.4% of the time whereas they chose high-BOI vehicles ($M = 3.918, SE = .103$) less frequently at 43.5% of the time.

Two interactions were observed. First, a vehicle-BOI by vehicle-SND interaction was observed, $F(1, 48) = 9.883, p = .003, \eta_p^2 = .171$. As is depicted in Figure 1, the effect of BOI differs for high and low-SND vehicles: low-BOI vehicles were preferred for both high and low-SND items but this preference was greater for low-SND vehicles than high-SND vehicles.

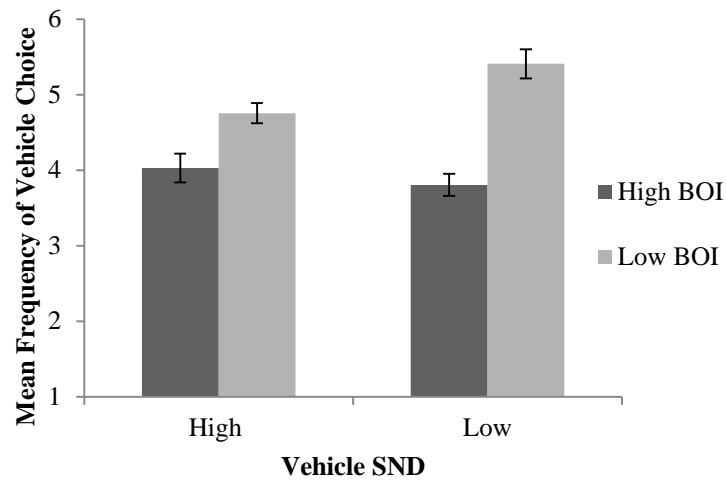


Figure 1. Vehicle SND by Vehicle BOI interaction in Experiment 3. Error bars represent standard error.

Second, a three-way, topic SND by vehicle BOI by vehicle SND, interaction was observed, $F(1, 48) = 9.089$, $p = .004$, $\eta^2 = .159$. As Figure 2 shows, the distribution of vehicle choices differs between high and low-SND topics. For high-SND topics, participants relied more on low BOI – low SND vehicles to construct apt metaphors. Presumably, this was to reduce the overall semantic richness of the metaphor because the topic is already from a dense semantic neighbourhood. Conversely, when the topic is from a sparse semantic neighbourhood, vehicle semantic richness does not matter as much.

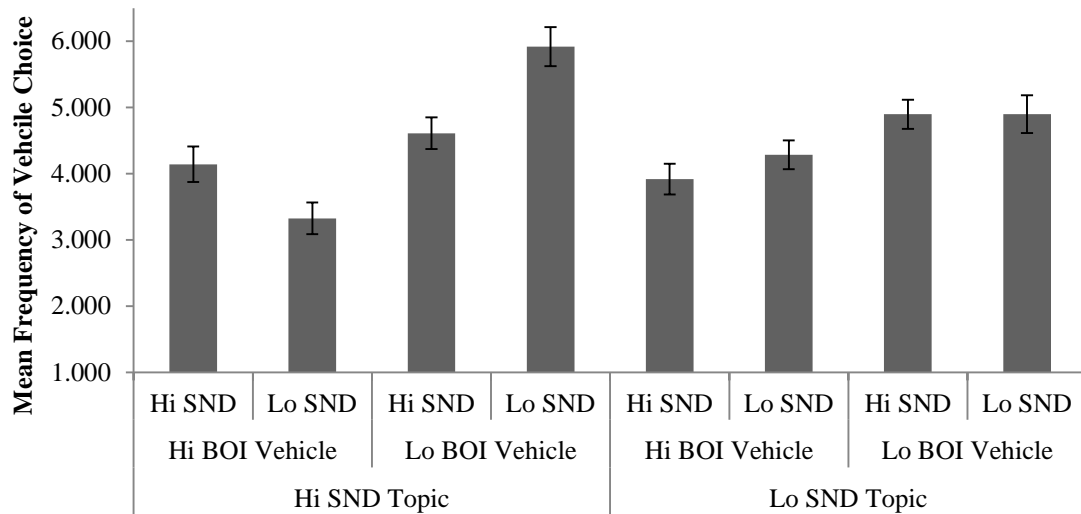


Figure 2. Condition means in Experiment 3. Error bars represent standard error.

The main effect observed in the metaphor production task for low-BOI nouns is consistent with the effects of Studies 1 and 2 where participants rated artificial metaphors for meaning. In Studies 1 and 2, metaphors with low-BOI vehicles were rated as more comprehensible than those with high-BOI vehicles, and in the current experiment, people choose low-BOI vehicles more than high-BOI vehicles when creating novel metaphors. I have argued that these low-BOI effects suggest that embodied simulation processes are not involved in metaphor processing. Moreover, the low-BOI effects are consistent with previous experiments on semantic richness in metaphor processing, which also showed that semantically rich concepts (i.e., defined by semantic neighbourhood density) negatively affected metaphor comprehension in both offline and online tasks (Al-Azary & Buchanan, 2017). To date, I do not know of any studies demonstrating semantic

richness (beyond concreteness of the vehicle) is conducive for metaphor processing (e.g., comprehension and production).

Like the main-effect, the interactions obtained here also demonstrate how semantic richness is detrimental to metaphor processing. That is, the low-BOI preference was greater when vehicles were also low-SND than high-SND, resulting in the most choices for vehicles that were low-BOI and low-SND. Moreover, the prevalence of choices for vehicles that are both low-BOI and low-SND was higher when the topic was high-SND rather than low-SND. These findings also fit within a framework where semantic richness is detrimental to metaphor processing. When the topic itself has many associations, and people must choose a vehicle to pair it with, they prefer low-BOI and low-SND vehicles, presumably to reduce the overall semantic richness of the metaphor. That is, the semantic representations of the topic and vehicle interact to produce meaning (e.g., Black 1962), and this interaction is most efficient when the semantic representations are not too constrained, but are flexible (e.g., Al-Azary & Buchanan, 2017). Therefore, the obtained main effect and interactions both extend the semantic richness hypothesis by showing the vehicles with sparser representations are favoured over those with richer representations. Presumably, semantically impoverished vehicles are more malleable to forming new associations in metaphor creation than their semantically rich counterparts.

Of course, the vehicle must not be too semantically impoverished. Virtually all metaphor processing theories view the vehicle as a source of semantic information that is

transported to the topic. Moreover, recall that Katz (1989) showed people choose concrete vehicles over abstract vehicles when creating metaphors. However, the results of this study further characterize the nature of concrete vehicles. Concreteness is typically enough richness for creating metaphoric meaning; additional richness, such as motor imagery and proximal semantic neighbours, seems to provide too much semantic information, on average.

Metaphor Interpretation Data

The interpretations of the 49 participants were assessed. Each participant created and interpreted 36 metaphors, resulting in a total of 1764 interpretations. Trials were removed from analyses if they were left blank or the participant wrote “I don’t know”, or if participants accidentally interpreted the same metaphor twice (which occurred in four cases). The number of trials removed was low (29 cases, or 1.67% of the data), and left 1735 metaphors and interpretations for analysis. Interpretations were then cleaned by removing button-presses recorded by the E-Prime software used to collect responses (e.g., spaces would be recorded such as {SPACE}), and corrected for spelling using a spell-checker, along with errors in grammar and punctuation.

The majority of interpretations involved explanations for why the created metaphor makes sense, oftentimes explaining the similarity between the topic and vehicle. The main question regarding the interpretation data is to what degree they contain perceptual-embodied language. The secondary question involves whether high-

BOI metaphors elicit interpretations containing more perceptual-embodied language than low-BOI metaphors.

In their resemblance to embodied simulations, interpretations varied widely, with some interpretations lacking any perceptual-embodied properties, some other interpretations depicting a dynamic scene enriched with sensorimotor properties, and some other interpretations showing a mixture. To illustrate the variability in interpretations, consider how three metaphors with the same vehicle, *butterfly*, were interpreted. For instance, one person created the metaphor *nostalgia is a butterfly*, and interpreted it as “*Butterflies are said to be happy and nostalgia is having a happy memory.*” This interpretation makes no reference to sensorimotor properties; rather, an association of the vehicle (i.e., *happy*) is applied to the topic. As such, this interpretation is consistent with amodal processes such as comparison or categorization.

Other interpretations can be considered moderately embodied in which the literal sense of the vehicle is described as moving, albeit in a limited way. For example, one person created the metaphor *luck is a butterfly* and interpreted it as “*It is hard to capture, especially when you are pursuing it, and it never stays for long.*” This interpretation compares pursuing and catching a literal butterfly to experiencing good luck. As such, it involves characteristics of a butterfly that would result from simulating what it must be like to catch a butterfly (i.e., *hard to capture, never stays for long*). Despite lacking a rich sensorimotor experience, the interpreter is considering dynamic, physical qualities of the vehicle beyond its relations and abstract properties (i.e., its ability to quickly move).

Lastly, some interpretations seemingly evoked the embodied simulations described by Gibbs and colleagues (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007), and by Paivio and Walsh (1993) where one simulates a scene with dynamic, rather than static, properties of the vehicle. For example, one person created the metaphor *amusement is a butterfly*, and interpreted it as follows; “*Have you watched a butterfly flutter from flower to flower? In the sunshine and the tall grass and wildflowers, that is truly amusing.*” This interpretation clearly involves a dynamic scene where the interpreter imagines a literal butterfly in its natural environment. Such simulations do not simply involve static perceptual properties; rather, the butterfly is in motion and other imagery is described (i.e. *sunshine, tall grass*). Moreover, the scene described has temporal order and events; that is, the butterfly is flying from flower to flower, in an apparent sequence.

The examples described above, and others, can be found in Table 4. Each sample interpretation was produced by a different participant. One particularly interesting finding is that the same continuum ranging from associative to embodied interpretations can be found for both high and low-BOI metaphors. This was not anticipated, as high-BOI was used as a means to invite embodied simulation. However, it seems from the sample interpretations that low-BOI items are also amenable to simulation. For example, recall the low-BOI metaphor described above, *amusement is a butterfly* involves a simulation of a literal butterfly in its natural environment as a source domain to describe the abstract concept, *amusement*. Similarly, a high-BOI metaphor, such as *imagination is a balloon*, likens releasing a balloon in the air and watching it float away with a child’s imagination.

Again, in this interpretation, a simulation involving a literal entity is taken as a source domain to describe an abstract concept. Therefore, it seems from the interpretation data, that high-BOI may not be a proxy for inviting embodied simulation; rather, concreteness alone may be sufficient.

Table 4. Sample interpretations varying in embodiment for high-BOI and low-BOI metaphors. Each interpretation was provided by a different participant.

Interpretation Type	High-BOI Metaphors	Low-BOI Metaphors
Disembodied	Prestige is a sword: One can either use their prestige for good or evil.	Nostalgia is a butterfly: Butterflies are said to be happy and nostalgia is having a happy memory.
	Luck is a balloon: Both bring most people joy but do not last forever.	Narcissism is a storm: Just like a storm is a bad thing that can cause havoc so can having a narcissistic demeanor.
Moderately Embodied	Secrecy is a sword: When people keep secrets or you keep secrets, it can create thick drama and can hurt someone as if a sword cut them.	Luck is a butterfly: It is hard to capture, especially when you are pursuing it, and it never stays for long.
	Narcissism is a balloon: Narcissistic people do things to make themselves feel better, and are constantly filling the balloon, or their ego, with air and don't know when to stop.	Hatred is a storm: Hatred is like a storm brewing inside of you and it doesn't do any good to hang onto hatred - until you let it go, your insides will feel like a storm.
Embodied Simulation	Guilt is a sword: Guilt is like an imaginary sword that is stuck in you. Even though you've probably used that sword to hurt someone else, it comes back to stab you.	Amusement is a butterfly: Have you watched a butterfly flutter from flower to flower? In the sunshine and the tall grass and wildflowers, that is truly amusing.
	Imagination is a balloon: Balloons represent children. Children like to imagine things, and they like to put in their energy and effort to blowing into the balloon, to make it large and to let it float into the air. The similarity lies in that both the balloon and the children's imagination reach an inevitable end, which is when reality sets in and breaks both entities.	Obsession is a storm: Just like how a storm can start off very small before it gets big and out of control, obsession can also follow the same path. Occasionally thinking about something can become uncontrollable to the point where you cannot help yourself from thinking about that thing with every waking moment. Obsession can also creep up on you without you knowing just like how a light shower can suddenly turn into a thunderstorm.

The Linguistic Inquiry and Word Count (LIWC) software was used to quantify the perceptual-embodied content of the interpretations (Pennebaker, Francis & Booth, 2001). The LIWC determines the percentage of words in a text that are from a particular category. For example, a text passage may contain words that are related to perception, motion, or the body, and therefore, reflective of embodied simulation. In fact, Zator and Katz (2017) used the LIWC to assess embodiment in people's verbally explained autobiographical memories. To analyze the degree of embodiment in the metaphor interpretations, I selected the following linguistic categories of the LIWC: *perceptual* words (e.g., *look*), broken down specifically by *seeing* (e.g., *view*), *hearing* (e.g., *listen*), and *feeling* (e.g., *touch*) words. I also included words relating to the *body* (e.g., *hands*), and *biological processes* (e.g., *eat*), along with words related to *relativity* (e.g., *bend*), *motion* (e.g., *arrive*), and *space* (e.g., *in*). As such, each of these subcategories will provide a finer grain analysis of metaphor interpretations than found in previous experiments (Siltanen, 1986; Fraser, 1993).

Each interpretation was inputted to the LIWC and the percentage of words from each of the categories described above was outputted. Therefore, for each interpretation, nine values representing embodiment were generated. The total word count for each interpretation was also obtained. Because each value represents only one dimension of embodiment (e.g., vision, motion, space, etc.), an average embodiment score was calculated as the mean of the nine sub-categories and therefore also expressed as a percentage. See Figure 3 for a histogram of the average embodiment scores. According to

the LIWC's definition of perceptual, bodily and motion related words, there is a wide variety of scores, ranging from zero to 19 percent.

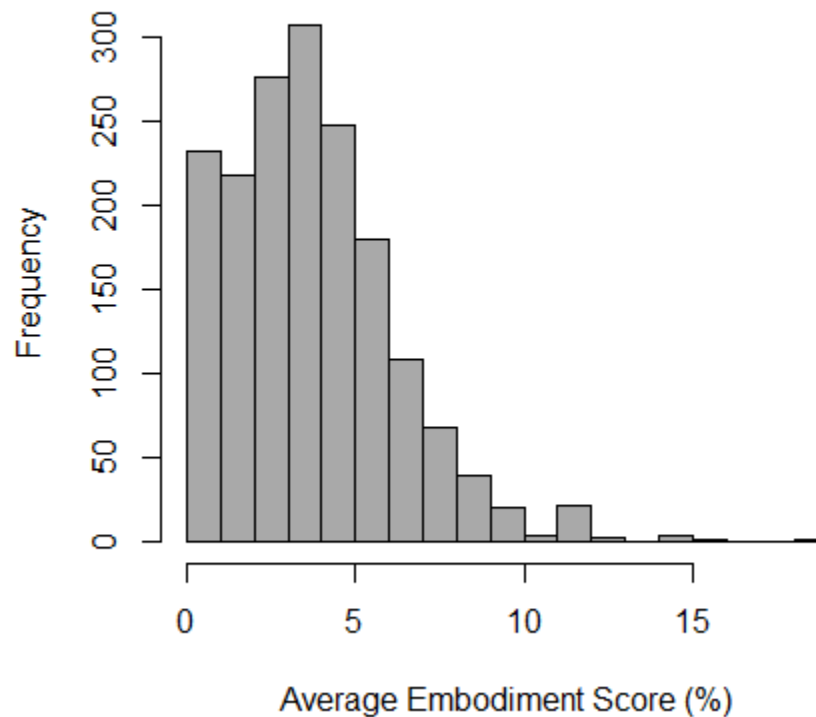


Figure 3. Histogram of Interpretations' Average Embodiment Scores.

For further analysis, the interpretations were grouped by vehicle-BOI. The aim of this analysis was to determine if high-BOI metaphors resulted in interpretations that contain language that is suggestive of an embodied simulation. As such, this was a check on my assumption that BOI is an appropriate variable to study embodied simulation in

metaphor processing. To that end, I compared the interpretations of the high-BOI metaphors ($N = 752$) with those of the low-BOI metaphors ($N = 983$) on average embodiment, along with the sub-categories related to embodied simulation described above. I anticipated that high-BOI metaphors would, on average, elicit interpretations with more words related to embodied simulation than low-BOI metaphors. I compared interpretations using independent samples t -tests. These comparisons are summarized in Table 5.

Table 5. Total word count and percentage of words from specific linguistic categories for high-BOI and low-BOI metaphors. p values are derived from independent samples t -tests with 1733 degrees of freedom.

Linguistic Category	High-BOI Metaphors (n = 752)	Low-BOI Metaphors (n = 983)	p
Total Word Count	19.13	18.21	0.08
Perceptual	3.2	3.89	< .05
See	1.27	2.04	< .001
Hear	0.23	0.18	.45
Feel	1.33	1.15	.25
Body	.30	.14	<.01
Biological	2.14	1.15	< .001
Motion	2.05	2.51	< .05
Space	7.84	8	0.685
Relativity	13.98	14.94	.08
Average Embodiment	3.59	3.78	.126

Surprisingly, as can be seen in Table 5, both high and low-BOI metaphors' interpretations are equal in their average embodiment scores. Moreover, low-BOI metaphors elicited interpretations with more perceptual-related, see-related, and motion-related words than high-BOI metaphors. This is counter to the anticipation that high-BOI words would be more amenable to movement, in terms of imaginary interaction, than low-BOI words. Conversely, and less surprisingly, high-BOI metaphors elicited

interpretations with words relating to body parts and biological processes more-so than low-BOI metaphors. This is not surprising because high-BOI words, by their nature, are more related to a human body than low-BOI words. It is worth noting that the differences between interpretations of high and low-BOI metaphors are small. In fact, both high and low-BOI interpretations were significantly higher than zero in each of the individual linguistic categories chosen to approximate embodied simulation (all p 's < .001). Therefore, despite BOI level, the interpretations, on average, contained words indicative of an embodied simulation. This result is particularly interesting because the participants were not encouraged to think of the actions or images that are associated with the metaphors before they interpreted them.

One critical implication of the interpretation data is that low-BOI effects reported in Chapter 1 and above can no longer be taken as suggestive of a disembodied processing mechanism. As Table 5 shows, low-BOI vehicles are advantaged in eliciting perceptual and motion related words in their interpretations, and on average, evoke embodied interpretations as much as high-BOI metaphors. Therefore, the low-BOI advantages reported in Chapter 1 can be just as suggestive of embodied simulation mechanism as the low-BOI advantage reported here, and provides an alternative explanation to the results obtained thus far. For instance, participants in Chapter 1 could have been engaged in embodied simulation processes while they were trying to understand the metaphors they were rating. Moreover, when creating metaphors, participants could have engaged in embodied simulation processes as they were choosing vehicles. In both comprehension

and production tasks, participants may have shown preference for low-BOI vehicles because they are in fact more amenable to some aspects of embodied simulation, such as those related vision and motion. Therefore, the interpretation data provides a more complete picture of how concrete concepts, despite their BOI level, can contribute to an embodied understanding of metaphorical meaning.

Recall that the inclusion of vehicle-SND was to examine, with vehicle-BOI, semantic richness effects in metaphor production. Moreover, the main focus of the interpretation data was on the degree of perceptual-embodied language used in general, along with the role BOI plays in eliciting such language, rather than the role played by SND. However, for the sake of completion, the same analysis of perceptual-embodied language was conducted for the interpretations broken-down by vehicle-SND¹¹. Table 6 shows that the interpretations for high and low-SND metaphors differ in their perceptual-embodied content. Metaphors with high-SND vehicles elicited interpretations containing more perceptual, hear, biological, and motion words, along with more average embodiment. On the other hand, metaphors with low-SND vehicles elicited interpretations containing more space-related words. Although not traditionally considered an embodied variable, SND appears to have a perceptual-embodied basis in metaphor interpretation, perhaps more-so than BOI. There is no a-priori explanation for vehicle-SND to be associated with perceptual-embodied language. However a post-hoc

¹¹ I am not conducting a factorial analysis because participants created vastly unequal numbers of items belonging to their respective semantic conditions.

speculation is that high-SND concepts, by chance, likely have more proximal semantic neighbours that are related to sensorimotor properties than do low-SND concepts, which have fewer near semantic neighbours in general.

Table 6. Total word count and percentage of words from specific linguistic categories for high-SND and low-SND metaphors. *p* values are derived from independent samples *t*-tests with 1733 degrees of freedom.

Linguistic Category	High SND Metaphors (n = 844)	Low SND Metaphors (n = 891)	<i>p</i>
Total Word Count	18.62	18.60	0.967
Perceptual	3.94	3.26	< .05
See	1.63	1.78	.507
Hear	0.30	0.11	<.01
Feel	1.31	1.15	.28
Body	.22	.21	.808
Biological	2.37	0.83	< .001
Motion	2.67	1.96	< .01
Space	7.52	8.32	<.05
Relativity	14.53	14.52	.986
Average Embodiment	3.83	3.57	<.05

General Discussion

Despite the fact metaphor interpretations are scarcely studied in psycholinguistics, there are some studies with which the present data are consistent. For example, Gibbs, Gould and Andric (2006) asked participants listen to metaphorical sentences such as *chew on the idea*, and then form mental images of the actions in the metaphor. The participants were then asked to explain how the action related (e.g., *chew*) to the noun (e.g., *idea*), and often times produced interpretations that depended on the literal action; for example, one participant explained *chew on the idea* to mean “*Chewing is related to a slow methodological activity and it could be related to turning something over in your mind to better understand it*”. This type of answer is consistent with many of the interpretations provided by participants in the current study. Gibbs et al. (2006) explained their data in terms of embodied simulations, where bodily-action is the basis of metaphorical understanding. However, unlike in Gibbs et al. (2006), participants in the current study were not asked to form a mental image of their metaphor prior to interpreting it, nor were they encouraged to think of potential actions that are consistent with the metaphor. Moreover, the metaphors interpreted by the participants are nominal, and hence do not refer to any performable actions. Therefore, the current dataset extend Gibbs et al. (2006) findings of embodied metaphor interpretations to nominal metaphors, and suggest the effect is robust enough to appear without prompting a particular interpretation strategy. Therefore, the ubiquity of the perceptual-embodied language used in the metaphor interpretations is consistent with the predictions of Gibbs’ simulation

model along with Paivio's dual coding theory of metaphor.

Although on average metaphor interpretations were significantly more embodied than zero, there was wide variability in interpretations' average embodiment scores, as Figure 3 showed above. In fact, nearly 10% of the interpretations did not include any language associated with embodied simulation whatsoever (when using the LIWC to detect language related to embodiment). Models that predict perceptual-embodied language in metaphor interpretation differ in how they explain such variability.

According to the dual coding theory of metaphor, processing is mediated by two-subsystems; the verbal and imagery systems. Recall that the verbal system primarily deals with linguistic information, such as associates, whereas the imagery system deals with multimodal information. Moreover, the image system stores a concept's multimodal properties in integrated structures. This type of integrated storage allows for the embodied interpretations to emerge. For example, the interpretations describing a butterfly among the flowers, tall grass, and sunshine, suggests that the vehicle concept, when used metaphorically, gave rise to entire perceptual scenes rather than only the image of a single concept. Clearly, imaging a butterfly brought to mind other perceptual properties which are analogous to the perceptual world. Moreover, recall that in DCT, the verbal system alone can underlie metaphor interpretations. This was evident in the less embodied interpretations, such as the *nostalgia is a butterfly* metaphor, where one participant considered how an associate of butterfly (i.e., *happy*) can be related to the topic, *nostalgia*. Moreover, moderately embodied interpretations seem to be defined by

indirect imagery along with verbal associates. As such, DCT explains the diversity in interpretations; most interpretations likely stem from mental imagery of the vehicle, which in turn, activates related verbal associates. In some cases, the vehicle's associates were enough to generate an interpretation, and as a result, the interpretations were scarce in imagery.

Alternatively, embodied simulation and mental imagery could always underlie metaphor interpretations, as put forward by Gibbs. Accordingly, interpretations with little to-no-mention of perceptual-embodied properties could arise simply because they were omitted from the written output. That is, in forming their interpretations, participants could have all simulated the sensorimotor properties of the vehicle, and then used this information to explain the relations or abstract properties shared by the topic and vehicle. In fact, Gibbs and Matlock (2008) stated that an embodied simulation may run alongside ad-hoc categorization processes (such as Glucksberg's 2008 model suggests). The important point here is that both dual coding theory and Gibbs' simulation theory can accommodate the wide-variety of interpretations obtained in this study. The difference between the two models is that in Gibbs simulation theory, embodied simulations are necessary for metaphor understanding. Therefore, if some metaphor interpretations are void of perceptual-embodied language, it is because the underlying embodied simulation is unconscious and therefore omitted from the overt interpretation. Conversely, in dual coding theory, metaphor understanding can be carried out primarily with the amodal representations of the verbal system. The role of the image system is not mandatory.

However, in most cases, both systems will provide contributions because they are interconnected. Therefore, the present data do not distinguish between dual coding and Gibbs' simulation theories; rather, both theories predict average metaphor interpretations to contain perceptual-embodied language.

Amodal theories, such as structure-mapping (Gentner & Bowdle, 2008) and categorization (Glucksberg, 2008) are mostly inconsistent with the obtained interpretations, which on average contained a significant amount of perceptual-embodied language. This inconsistency is especially true of the categorization model; recall that many of the interpretations contained literal reference of the vehicle. That is, a metaphor with *butterfly* as its vehicle elicited an interpretation that referred to a literal butterfly. Therefore, the categorization model in its current form is inconsistent with how people interpret metaphors. Structure-mapping also predicts little-to-no perceptual language in adults' interpretations of metaphors. However, it treats the vehicle as a literal concept, and is therefore more consistent with the obtained interpretations than the categorization model. For example, structure-mapping can be amended to accommodate the obtained data. Recall that in structure-mapping, the topic and vehicle are aligned and attributes (which can be perceptual features) are mapped, and then relations of the vehicle are projected to the topic. It could be the case that, in the alignment stage, people are imagining the perceptual-embodied features of the vehicle to a greater extent than what is typically given in structure-mapping. Therefore, before the relations of the vehicle are identified, participants engage in an embodied simulation to infer what the shared

attributes between topic and vehicle may be (Gibbs & Matlock, 2008). However, the important point to consider here is that both structure-mapping and categorization, in their current forms, do not adequately explain the perceptual-embodied language used in the metaphor interpretations obtained in the current study.

Conclusions

The metaphor creation task demonstrated that vehicle choice is affected by semantic richness. In creating metaphors, low-BOI concepts are preferred as vehicles more-so than high BOI concepts and this preference is magnified when the vehicle is also low-SND. Moreover, the low BOI-low SND vehicles are chosen the most when they are paired with a high-SND topic. In all cases, the data suggest that semantic richness makes it difficult for one to create novel metaphoric meaning. As such, people choose vehicles that will result in low semantic richness of the metaphor. Although the BOI and SND effects in the vehicle selection task are consistent with previous theory, their effects on metaphor interpretation are not straightforward. That is, high-BOI metaphors do not seem to invite embodied simulation more-so than low-BOI metaphors. Conversely, high-SND metaphors do seem to invite embodied simulation more-so than low-SND metaphors. As such, these variables will no longer be employed as proxies for embodied or amodal processing in the remainder of the studies in this dissertation.

On average, metaphor interpretations contained perceptual-embodied language. This suggests the involvement of embodied simulation (or mental imagery). This is consistent with predictions resulting from both dual coding theory (Paivio & Walsh,

1993) and Gibbs' simulation theory (Gibbs & Matlock, 2008), but does not distinguish between the two. Classic theories such as structure-mapping (Gentner & Bowdle, 2008) and categorization (Glucksberg, 2008) are inconsistent with the metaphor interpretations.

The metaphor interpretation task proved to be effective as a more sensitive test to detect embodied simulation than the comprehension-rating task used in Chapter 1.

However, the interpretation task is an offline measure; as such, it does not demonstrate if embodied representations are immediately accessed when one interprets a metaphor. In Chapter 4, this research question is addressed.

Chapter 4

Introduction

The interpretations of the metaphors created in the previous chapter suggest the use of embodied simulation in metaphor processing. On average, people used perceptual, bodily, and motion related language to describe scenes or events that involved the metaphors' vehicle referent. Oftentimes the metaphor vehicle was used in a literal, physical sense. This is precisely the speculated embodied simulation mechanism for nominal metaphors (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007; Paivio & Walsh, 1993). However, interpretation tasks such as those described by Gibbs and Matlock (2008) and used in the previous chapter are offline and, as such, they do not characterize the time-course of processing. This raises questions regarding when embodied properties become available for use in interpreting the metaphor. For example, did people use an amodal or verbal associative approach to create metaphors, and then embellish the meaning with embodied simulation when they were asked to interpret them? Or, alternatively, was an embodied simulation active throughout the entire process thus, constraining the interpretations? It is possible too, that those seemingly disembodied interpretations observed in Chapter 3 arose from embodied simulation comprehension mechanisms, but any details related to the simulation were omitted from the reports produced as interpretations. In the current chapter these questions will be addressed by determining if embodied representations are accessible during online metaphor processing.

Embodied Simulation of Language

Evidence that embodied simulation underlies language comprehension comes from interactions between the embodied properties implied in sentences and performing sensorimotor tasks. This is exemplified by the action-sentence compatibility effect (ACE), discovered by Glenberg & Kaschak (2002). An ACE occurs when the implied motion in a sentence interacts with the physical motion required to make a response followed by reading the sentence. For example, in the sentences, *open the drawer*, *Courtney gave you the notebook*, and *Liz told you the story*, the implied motion is movement toward oneself. Embodied simulation is identified if a response about the sentence (i.e., sensibility) is made faster when the hand must be brought toward oneself to push a response-key than when it must be moved away from oneself to push a response key. The opposite is true for sentences implying motion away from oneself (e.g., *close the drawer*, *you gave Courtney the notebook*, *you told Liz the story*, etc.); in those cases, the response key that is far and thus requires movement away from oneself is pushed faster than the closer response key. These effects, where a physical movement is made faster if it is preceded by a sentence implying motion in the same direction, are taken as evidence that the semantic properties of sentences are being simulated.

Congruency effects similar to the ACE are observed also when mental imagery is assumed to be activated. For example, Zwaan, Stanfield and Yaxley (2002) had participants read sentences such as *the ranger saw the eagle in the sky* and *the ranger saw the eagle in its nest*. After reading a sentence, a picture of an object appeared on the

screen. Participants were asked to determine if a presented picture contained an object that was mentioned in the sentence [Experiment 1], or simply had to name it [Experiment 2]. In both cases, response latencies were shorter for pictures that matched the orientation implied in the sentence; for example, a picture of an eagle with wings extended matches the sentence *the ranger saw the eagle in the sky* whereas a picture of an eagle with wings folded matches the sentence *the ranger saw the eagle in its nest*. In a similar experiment, Zwaan, Madden, Yaxley and Aveyard (2004) employed sentences implying physical motion of an object coming toward or away the participant, such as *you hurled the softball at the shortstop*, or, *the shortstop hurled the softball at you*. After the auditory presentation of a sentence, participants determined if two serial images contained the same object. The objects in the images varied in size. A congruency effect was found such that if the sentence implied motion away from the participant, then responses to images of a large softball followed by a smaller softball (suggesting the ball is moving away) were made faster than to images of a small softball followed by a larger softball (suggesting the ball is moving toward). The opposite finding was observed for sentences that implied motion toward the participants.

The aforementioned studies demonstrate that people simulate at least some of the embodied and perceptual properties implied within sentences. However, Matlock (2004) demonstrated simulation of *fictive* motion sentences, such as *the road runs through the desert*. Such sentences do not imply actual motion or perceptual changes. In her task, participants read stories about someone traveling through an environment (e.g., a desert).

In the stories, the travel was described as either short or long [Experiment 1], rapid or slow [Experiment 2], or through easy or difficult-to-traverse terrain [Experiment 3]. After reading a story, participants read sentences that described fictive motion, such as *the road runs through the desert* and decided if it was related to the story read prior. The fictive motion sentences were read faster when they were preceded by stories implying short travel times (e.g., short distance, rapid travel, travel over easy terrain) than by stories implying long travel times. No effects were found in control experiments, where the sentence does not imply fictive motion (e.g., *the road is in the desert*). A follow-up experiment found this effect to be present in fictive motion sentences unrelated to travel, such as *the fence follows the property line*, further demonstrating the robustness of the effect. Such findings are taken to suggest that participants constructed an embodied simulation of the stories, and this influenced the reading of subsequent fictive motion sentences.

Embodied Simulation and Metaphor Comprehension

The evidence of embodied simulation reported above comes from studies where researchers employed sentences varying in abstraction; nonetheless, they are all literal sentences that are relatively easy to imagine. However, embodied simulation is thought to underlie metaphoric language as much as it does literal language (e.g., Lakoff & Johnson, 1980). Wilson and Gibbs (2007) provide the strongest demonstration of embodied simulation underlying metaphor comprehension. In their task, participants read sentences

which use a verb metaphorically, such as *grasp the concept*, or, *swallow your pride*, and pushed a key when they felt they understood them. However, prior to reading the sentences, the participants learned to perform the actions mentioned in the sentences, such as grasping and swallowing, by watching an actor perform them. Moreover, the actions were never associated with a verbal label. Instead, the actions were associated with an arbitrary icon (e.g., the symbol # was associated with the action of swallow; the symbol “ was associated with grasp, etc.). Prior to reading the sentences, participants were prompted, by the presentation of the icon, to perform an action. When participants performed actions congruent with the sentences (e.g., physically swallowing prior to reading the sentences *swallow your pride*), reading times were facilitated relative to performing incongruent actions or no actions at all. Interestingly, this effect was replicated when participants were asked to merely imagine the action instead of physically carrying it out.

The metaphors used in Wilson and Gibbs (2007) are conventional figures of speech. Other studies demonstrate a link between novel metaphor comprehension and embodied simulation. For example, Slepian and Ambady (2014) showed that novel metaphors can affect sensorimotor judgements. In their task, participants learned one of two novel metaphors; *the past is heavy*, or, *the present is heavy*. After learning the metaphors (which involved reading a passage describing how the past or present could be figuratively heavy), participants were asked to judge the weight of a visibly old or new book by either physically holding the book, or judging its weight from inspecting a photo

of the book. For those judging the weight of the old book, participants in the past-is-heavy condition judged it to be heavier than participants in the present-is-heavy condition; the opposite was true for those in the present-is-heavy condition. Importantly, those making judgements of the book's weight by viewing photographs showed no effects.

Another study showing a link between metaphor comprehension and sensorimotor processes found differential EEG scalp distributions for auditory and motion based metaphors (Schmidt-Snoek, Dew, Barile & Agauas, 2015). In this study, participants read motion metaphors, such as *the rejection letter was a slap* and auditory metaphors such as *her marriage was a long sob*. The final words were matched on numerous variables known to influence ERPs, including cloze probability. ERPs time-locked to the presentation of the final word (e.g., *slap*, *sob*) were recorded. Other than typical N400 effects, such as larger negativities for anomalies than metaphors, and metaphors than literals, the scalp distribution of the N400 for the motion and auditory metaphors differed in left-center, left-posterior, and centre-posterior regions. Therefore, the modality underlying metaphorically used words may be reflected in the underlying neural generators, suggesting modality specific processing.

Despite the seemingly positive evidence reported above, one must be cautious in evaluating the studies reporting a link between metaphoric language and embodied simulation. For example, of the studies reported above, only Wilson and Gibbs (2007) demonstrated facilitation in metaphor comprehension times as a result of performing or

imagining a consistent bodily action. Conversely, Slepian and Ambady (2014) did not measure metaphor comprehension. As such, they can only report a relationship between learning a novel embodied metaphor and sensorimotor processing. In fact, it is possible that their participants learned the metaphors using amodal processes, and then after some time, created the conceptual embodied mapping between the past/present and heaviness, in time for the sensorimotor judgements. Schmidt-Snoek et al.'s (2015) results are also not convincing of embodied simulation underlying metaphor comprehension. For example, it is possible that the difference in N400 scalp distributions between motion and auditory metaphors was due to initial processing the words' literal referent. This is likely, as their study showed differences in auditory and motion based *literal* sentences in addition to the metaphors. Therefore, not all embodied simulation effects are as convincing as those reported by Wilson and Gibbs (2007).

One characteristic with the studies reported above is they utilize stimuli that overtly reference a sensorimotor property. That is, the metaphors *the past is heavy*, *swallow your pride* or *the rejection letter was a slap*, although different in form, all use words that unambiguously denote a sensorimotor representation (i.e., *heavy*, *swallow*, *slap*). These types of metaphors are therefore fair candidates for evoking sensorimotor representations; however, this raises the question about the potential of the embodied simulation of the classic resemblance metaphors studied in psycholinguistics, such as *lawyers are sharks*. Such metaphors do not directly denote a sensorimotor activity. Therefore, it is difficult to study the potential embodied simulation of nominal metaphors

because they may evoke multiple sensorimotor properties. As such, it is difficult to determine precisely which sensorimotor properties of sharks, for example, may be involved. This is especially true if comprehending nominal metaphors involves an ‘as if’ scenario, where one must simulate what it must be like to be the vehicle concept (Gibbs & Matlock, 2008), or construct a dynamic scene where the vehicle concept is imagined (Wilson & Gibbs, 2007). In either case, according to embodied simulation theory, sensorimotor properties related to the vehicle ought to be employed during processing.

Demonstrating a relationship between processing metaphors and performing physical actions is impractical with nominal metaphor stimuli. For example, a study like Wilson and Gibbs (2007) cannot be replicated using nominal metaphors such as *lawyers are sharks* or *suburbs are parasites* because sensorimotor properties related to sharks or parasites cannot be performed by a participant in the same way as bodily-action verbs such as *push* or *swallow*. However, psycholinguistic tasks, such as cross-modal lexical priming (CMLP), were developed to study the activation of associative or semantic properties during sentence comprehension (Swinney, 1979). In this task, subjects hear linguistic stimuli and perform lexical decisions at varying time-points to assess when particular properties are activated, or responded to faster, relative to others. Although it was first used by Swinney (1979) to study lexical ambiguity resolution, Blasko and Connine (1993) extended the procedure to metaphor processing. In their experiments, participants heard metaphors in context, such as *the belief that hard work is a ladder is common to this generation*, and made lexical decisions to words related to the metaphor’s

meaning (e.g., *advance*), the literal meaning (i.e., *rungs*) and an unrelated control word (e.g., *pastry*). Their overall results showed that for apt metaphors (both familiar and unfamiliar), the metaphoric related word is activated (i.e., faster than controls) immediately after hearing the vehicle. For inapt metaphors, the metaphoric meaning is available 750 ms after vehicle offset.

In another CMLP metaphor study, Rubio-Fernandez (2007) compared the activation of different category-level properties of the vehicle. For example, in *John is a cactus*, the vehicle's category is *plant* whereas its distinctive feature is *prickly*. Immediately after vehicle offset, both properties are activated (i.e., faster than controls) but the activation for *plant* is suppressed by 1000 ms, (i.e., equivalent to controls) whereas *prickly* remains activated. Therefore, the CMLP technique has been repeatedly employed to assess if properties relevant for metaphor processing are activated online.

The CMLP technique can be extended to determine if sensorimotor properties related to the vehicle are accessible during metaphor comprehension. For instance, suppose one hears *lawyers are sharks* in a context. If this metaphor is simulated in the way described by Gibbs and colleagues, then bodily-actions related to sharks should be primed when processing the metaphor. Recall that Gibbs' model placed special emphasis on bodily-actions, perhaps more-so than other sensorimotor processes. Therefore, the word *bite*, which is an associate of shark, ought to be responded to faster than a bodily-action unassociated with shark, such as *enter*. If so, this would suggest people can access sensorimotor properties of the vehicle, which will be supportive of the embodied

simulation framework.

Determining if a metaphor-vehicle primes bodily-actions is a more direct method to test embodied simulation than manipulating vehicle-BOI, which was done in Chapters 2 and 3. Recall that BOI refers to the perceived ease of interacting with a word's referent (Siakaluk et al., 2008). Nonetheless, this variable does not seem to be an appropriate proxy for embodied simulation of metaphor, as the previous chapter showed both low and high-BOI metaphors elicit interpretations containing perceptual-embodied language. Rather than consider the ease to interact with a vehicle's referent, in the current study the activation of associates that denote particular bodily-actions of the vehicle were considered. As such, this current conceptualization is similar to using BOI, as motoric properties of the vehicle are under examination. However, unlike using BOI, the current method will directly test the activation of specific actions related to the vehicle.

It may seem counter-intuitive for a nominal metaphor to prime bodily-actions, especially when the vehicle concept is not described to be in a state of motion, such as in *lawyers are sharks*. However, evidence from Masson, Bub and Warren (2008) suggests that embodied information is activated even if it is apparently unrelated to the sentential context. In their task, participants heard sentences (e.g., *the young lawyer kicked the calculator*) and then were cued to perform hand-actions related or unrelated to the object (not the verb) in the sentence (e.g., related actions to calculator could be a poke, whereas unrelated actions could be a pinch). The speed at which actions were performed was measured, and activation was determined by subtracting time taken to perform related

actions from time taken to perform unrelated actions. Their results showed that hearing a sentence such as *the young lawyer kicked the calculator* activates bodily-actions related to calculator, such as poking or grasping, despite their irrelevance to the context. Even sentences that do not describe any motoric interaction, such as *the young lawyer looked at the calculator*, still prime functional body-actions related to the referent. Therefore, it seems plausible that bodily-action words associated to a metaphor vehicle can be primed, despite their apparent irrelevance to the context in general.

The Current Studies

In the experiments in this chapter (i.e., Studies 4 – 7), a cross-modal lexical priming design was used to assess the activation of semantic properties related to metaphor vehicles. In the first two studies, metaphors in a context served as auditory primes (e.g., *everyone in the courtroom saw how those lawyers are sharks*) for visually presented target words. The target words were presented immediately after the offset of the vehicle in Study 4, and after a 1000 ms inter-stimulus interval (ISI) in Study 5. Studies 6 and 7 were carried out as control experiments where the vehicle alone served as an auditory prime (e.g., *sharks*) for zero and 1000 ms ISI durations, respectively. For all the studies, target words were semantic properties of the vehicle in the form of free associates (Nelson et al., 2004) along with unassociated control words. Two distinct types of associates were used; namely, bodily-action associates and general associates.

Bodily-actions are anything involving a body that one can themselves perform, or

imagine another organism performing (human or otherwise). As such, they can vary in the motoric sequences required to perform them; for example, a bodily-action related to the word *sharks* is *bite* whereas a bodily-action related to the word *sword* is *fight*.

Although *bite* and *fight* may differ in their respective motor sequences, with *fight* being arguably more complex than *bite*, they are both activities that can be simulated as a result of processing the respective metaphors they are related to. In Gibbs' and colleagues (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007) conception of embodied simulation (and Paivio's conception of mental imagery), a relatively rich scene is constructed. As such, there are likely numerous bodily-actions related to any given simulation which should be activated during online metaphor processing.

It should be noted that activation of bodily-action associates of the vehicle is not evidence in support of associative models of metaphor comprehension (e.g., Genter & Bowdle, 2008; Glucksberg, 2008; Kintsch, 2000) which I have described as amodal. Although in amodal models it is assumed that metaphor processing involves associates, such models do not consider bodily-actions to play a primary role. As such, amodal models predict no activation of bodily-action associates in the same way embodied models do. However, amodal models predict activation of general associates that are drawn from an abstracted sense of the vehicle.

Associates of the metaphor vehicle that refer to general properties (e.g., *killer* is a general associate of *shark*) were used as a proxy for amodal processing, as described in categorization and structure-mapping. Recall that in the categorization model, the

metaphor vehicle does not refer to a literal-level concept, but rather refers to an abstraction (Glucksberg, 2008). For example, the word *shark*, when used metaphorically, only refers to abstract properties related to a broader class of concepts (e.g., *vicious*, *predatory*, etc.). Similarly, in structure-mapping, metaphor processing entails extracting figurative relations from the vehicle rather than concrete attributes (Gentner & Bowdle, 2008). Therefore, both categorization and structure-mapping lead to the prediction that metaphor processing results in the activation of general properties rather than sensorimotor properties. As such, the general associates used in the following studies are related to the figurative and relational sense of the vehicle, and their activation is therefore consistent with the way metaphor processing is described in the categorization and structure-mapping models.

Another manipulation in this study is metaphor familiarity. Familiarity is an important consideration for testing theories of metaphor comprehension. In respect to embodied simulation, theories differ on the automaticity of sensorimotor processing. For example, in Gibbs' simulation theory, it is argued that sensorimotor processing is mandatory for metaphors, regardless of their familiarity (Gibbs & Matlock, 2008). Conversely, sensorimotor shedding theory places familiarity as the determinant factor of sensorimotor processing (Jamrozik et al., 2016). Accordingly, unfamiliar metaphors are processed by embodied simulation whereas familiar metaphors are processed amodally. As such, familiarity can adjudicate between Gibbs' simulation model and sensorimotor shedding.

Familiarity can also adjudicate between amodal models of metaphor processing. In structure-mapping (specifically the career-of-metaphor hypothesis), unfamiliar metaphors are described to be processed by drawing figurative relations from a literal representation of the vehicle. However, as metaphors become more familiar, the figurative relations become crystallized and more readily available than in unfamiliar metaphors (Bowdle & Gentner, 2005). Therefore, according to the structure-mapping model, unfamiliar metaphors may initially prime bodily-actions, but only to a lesser extent than general properties. However, familiar metaphors should only prime general properties. In the categorization model, metaphor familiarity does not play a particular role (Glucksberg, 2008). Therefore, according to this model, both unfamiliar and familiar metaphors should only prime general associates.

The final variable under consideration is the duration of the inter-stimulus interval (ISI) between the offset of the vehicle and the onset of the target. Like most cross-modal designs, an ISI of 0 ms was used to assess the upstream activation of semantic associates of the vehicle. At this time-course, all associates are typically activated (Swinney, 1979). Moreover, an ISI of 1000 ms was used to assess the downstream activation of properties. Recall that Rubio-Fernandez (2007) found that by 1000 ms, vehicle properties irrelevant to the metaphoric meaning are no longer activated; however, those properties that are relevant remain activated. Therefore, the downstream time-frame will assess whether or not bodily-actions and general properties are relevant for familiar and unfamiliar metaphors.

Four studies are reported in this chapter. In Study 4, participants were played metaphors spoken in a context (e.g., *my dad reminded to drive slow and stay alert because highways are snakes*) and performed lexical decisions to visually presented associates of the vehicles that are classified as bodily-actions (i.e., *slither*) or general properties (i.e., *danger*) along with unassociated control words and non-words. The target words and non-words were presented immediately after the offset of the vehicle (i.e., 0 ms ISI). Moreover, the metaphors were either unfamiliar (e.g., *highways are snakes*) or familiar (e.g., *alcohol is a crutch*). This task was replicated in Study 5, with the only exception being that the ISI was 1000 ms in order to examine downstream effects. In Study 6, participants were only played vehicles (e.g., *snakes*) and performed lexical decisions on the same items visually presented immediately at the offset of the vehicle. Lastly, in Study 7, participants again were played the vehicle in isolation, but performed lexical decisions to visual stimuli presented after a 1000 ms ISI.

Study 4

Method

Participants

Ninety-six undergraduate students from the University of Western Ontario participated for partial-course credit toward a psychology course. Participants were native speakers of English.

Materials

Metaphors

Twenty-four nominal metaphors used in the experimental trials were selected from Roncero and Almeida's (2015) items, which are normed on familiarity and aptness. Metaphors were chosen on the basis that the vehicle term was also in the Nelson et al. (2004) free association norms. Furthermore, all of the metaphors had different vehicles, to ensure repetition effects would not take place within the experiment (see Bowdle & Gentner, 2005). Metaphors below the median on familiarity (i.e., 4.15) were considered 'unfamiliar' ($M = 2.53$; range: 1.2 – 4.05) whereas those above were considered 'familiar' ($M = 6.23$; range: 5.2 – 7.7). The items differed significantly on familiarity, $t(22) = 10.19$, $p < .001$. Although care was taken to choose metaphors that were sufficiently apt (metaphors were all above three on a 1-10 aptness scale), the novel ($M = 5.02$) and familiar ($M = 7.06$) metaphors significantly differed on aptness, $t(22) = 3.98$, $p < .001$. Twenty-four other metaphors, comparable to the experimental items, were chosen for the non-word trials.

For each metaphor, a context in which the metaphor is plausible was created. For example, for the unfamiliar metaphor *pets are kids*, the context is *the vet likes to remind her clients that pets are kids*. The contexts were meant to bias the listener to process the metaphor figuratively. Moreover, all of the contexts were constructed so that they precede the metaphor, which was always uttered at the end of the sentence, resulting in the vehicle being the last word. A female native speaker of English was recorded reading

aloud the sentences. Audio files were trimmed at the offset of the vehicle, normalized, compressed, and put through a limiter, to make the sentences clearer than the original raw file. Pilot studies with those unfamiliar with the materials confirmed the sentences were audible.

Associates

Each vehicle's associates were searched for words that refer to bodily-actions and general properties in the Nelson et al. (2004) free-association norms. In cases where the vehicle was a plural word unavailable in the Nelson database, (e.g., *sharks*), the singular form (e.g., *shark*) was searched. Two critical associates for each vehicle were selected.

First, associates that refer to bodily-actions that can be performed by a human, or imagined to be performed, were selected as long as they were generally consistent with what an embodied-simulation reflecting the metaphor's meaning may entail (e.g., *bite* is an associate of shark that is consistent with the meaning of the metaphor *lawyers are sharks* because it is an aggressive action). Second, general associates were those that did not refer to an overt bodily-action, but still consistent with the metaphor (e.g., *killer* is an associate of shark); general associates are analogous to Glucksberg's (2008) attributive category properties and are therefore, more abstract than the bodily-action associates. It is important to note that, when choosing the associates, any word that was obviously unrelated to the metaphoric meaning was avoided. For example, some associates of *shark* that are likely unrelated to the metaphor meaning are, *white*, *fin*, *whale*, *fish*, *meat*, etc.

Both of the selected associate types did not significantly differ in their forward associative strength to the vehicle or in semantic distance to either the vehicle or topic (using Latent Semantic Analysis). See Table 7 for means and p -values.

Table 7. Forward strength (FSG) between vehicle and associates, along with semantic distance to the vehicle (SD-V) and topic (SD-T) for unfamiliar and familiar metaphors. Semantic distances are determined from latent semantic analysis (LSA). p values reflect two-tailed t tests.

	Unfamiliar Metaphors			Familiar Metaphors		
	Bodily-Action Associate	General Associate	p	Bodily-Action Associate	General Associate	p
FSG	0.06	0.08	0.62	0.03	0.05	0.14
SD-V	0.30	0.23	0.31	0.33	0.23	0.13
SD-T	0.11	0.14	0.63	0.13	0.08	0.27

Control Words

For each associate, a word matched on unprimed reaction-time (within 1.5 milliseconds) was selected to serve as a control unrelated to the vehicle. The English Lexicon Project database was used to determine unprimed reaction times (Balota et al., 2007). For example, the control word for the bodily-associate *bite* is *enter* whereas the control for the general associate *killer* is *jeans*. Although cross-modal designs typically use one type of control word (e.g., Tabossi, 1996), I opted to use two because the fundamental difference between the associates; namely, that one type refers to a bodily-action (i.e., verbs) and the other refers to a general property (i.e., mostly nouns or

adjectives)¹². Therefore, facilitation effects would be better calculated if the control word differs from the associate only in its relationship to the vehicle, rather than other characteristics as well. Because control words were matched on unprimed reaction time, they were not matched on other variables.

So that participants heard metaphors only once, four lists were created. Each list had 24 experimental metaphors along with a set of three visually presented word targets from each of the four conditions (i.e., bodily-action associate, bodily-control, general associate, general control). Each list had the same non-words, which were derived from the English Lexicon Project, and paired with a filler metaphor. See Appendix D for complete list of stimuli.

Procedure

Participants were made aware that the experiment is about metaphor processing, and were notified that they would hear sentences which ended in metaphors. They were told to try to understand the metaphorical meaning of the sentence. E-Prime software was used to present the audio files and visual stimuli, and record reaction times and responses. Each trial consisted of the audial presentation of the sentence, during which, a fixation cross remained on the screen. Zero ms after the end of the sentence (the offset of the vehicle), a letter-string replaced the fixation cross and remained onscreen until a response

¹² Thanks to Karen Hussey for this suggestion.

was made. Participants were instructed to quickly but accurately categorize the letter-string as a word, by pressing the M key, or a non-word, by pressing the Z key. There were two practice trials and 48 experimental trials, 24 involving words and 24 involving non-words. Experimental trials were presented in a random order.

Results

Trials with incorrect responses (3.8% of total dataset) were flagged. Of the errors, 60.45% were to non-words. The remaining errors for word trials are broken down by condition in Table 8. As can be seen, error rates are not uniformly distributed across conditions with the greatest percentage of errors for familiar metaphors being for general-unrelated words whereas for unfamiliar metaphors it is for unrelated bodily-actions. Means and standard deviations can be found in Table 9. Because the highest percentages of errors are for the relatively slow conditions, a speed-accuracy trade off does not appear to be present.

Table 8. Table 8. Percentage of errors broken down by associate type and metaphor familiarity for Study 4.

Word Type	Unfamiliar Metaphors	Familiar Metaphors
Bodily-Action Related	2.26%	2.82%
Bodily-Action Unrelated	12.43%	5.65%
General Related	0.56%	1.13%
General Unrelated	1.13%	13.56%

Table 9. Mean reaction times and standard deviation by each condition for Study 4.

Metaphor	Target Word	Relatedness	M	SD
Familiar	General	Rel.	611	162
		Unrel.	653	165
	Bodily-Action	Rel.	628	181
		Unrel.	656	179
Unfamiliar	General	Rel.	599	154
		Unrel.	615	132
	Bodily-Action	Rel.	617	155
		Unrel.	676	194

To clean the data, the same procedure was used in the all the studies reported in this chapter. Of the correct word responses, RTs greater than 2000 ms or less than 300 ms were removed (1.12%)¹³. For the subject-level analysis (F_1), a 2 (metaphor familiarity: familiar vs unfamiliar) by 2 (associate type: bodily-action vs general) by 2 (associate relatedness: related vs unrelated) repeated measures ANOVA was conducted, with list as a between-subjects factor. For the item-level analysis (F_2), familiarity and list are

¹³In the CMLP literature, a wide-range of cut-offs are used. I opted to use 2000 ms as it was the highest reported in the CMLP literature (e.g., Holcomb & Anderson, 1993), and as such, would clean the data without removing excess trials. Holcomb and Anderson used 200 ms as the lower-end cut-off. However, in Studies 4 and 5, all RTs were above 300 ms. In Studies 6 and 7, some RT's were below 300 ms. For consistency across all studies reported herein, I opted to use 300 ms as the lower cut-off for Studies 6 and 7.

between variables whereas associate type and relatedness are within variables. For both analyses, list is of no theoretical importance; rather, it was included as a factor to reduce error variance. Therefore, effects involving list will not be reported.

A main-effect of associate was obtained, $F_1(1,92) = 10.59, p = .002, \eta_p^2 = .103$; $F_2(1,16) = 4.63, p = .047, \eta_p^2 = .224$. On average, general associates ($M = 620$ ms) were responded to faster than bodily-action words ($M = 645$ ms). A main-effect of familiarity was nonsignificant, $F_1(1, 92) = 1.67, p = .199, \eta_p^2 = .017$; $F_2(1, 16) = .171, p = .685, \eta_p^2 = .011$. However, a familiarity by associate interaction was obtained in the subject analysis, $F_1(1,92) = 4.25, p = 0.042, \eta_p^2 = 0.044$, but not the item analysis, $F_2(1, 16) = 1.679, p = 0.213, \eta_p^2 = .095$. A main-effect of relatedness was obtained, $F_1(1,92) = 21.35, p < .001, \eta_p^2 = .188$; $F_2(1,16) = 5.26, p = .036, \eta_p^2 = .247$. On average, related words ($M = 614$ ms) were responded to faster than unrelated words ($M = 650$ ms). Relatedness did not interact with familiarity, $F_1(1, 92) = .03, p = .863, \eta_p^2 = 0.0$; $F_2(1, 16) = .007, p = .934, \eta_p^2 = 0.0$, or associate, $F_1(1, 92) = 1.05, p = .308, \eta_p^2 = 0.01$; $F_2(1, 16) = .307, p = .587, \eta_p^2 = 0.019$. Critically, a three-way familiarity by associate by relatedness interaction was observed, $F_1(1,92) = 4.04, p = 0.047, \eta_p^2 = 0.042$; $F_2(1,16) = 4.68, p = .046, \eta_p^2 = .226$. To interpret the three-way interaction, the facilitation effects (facilitation = unrelated RTs – related RTs) are graphed in Figure 4.

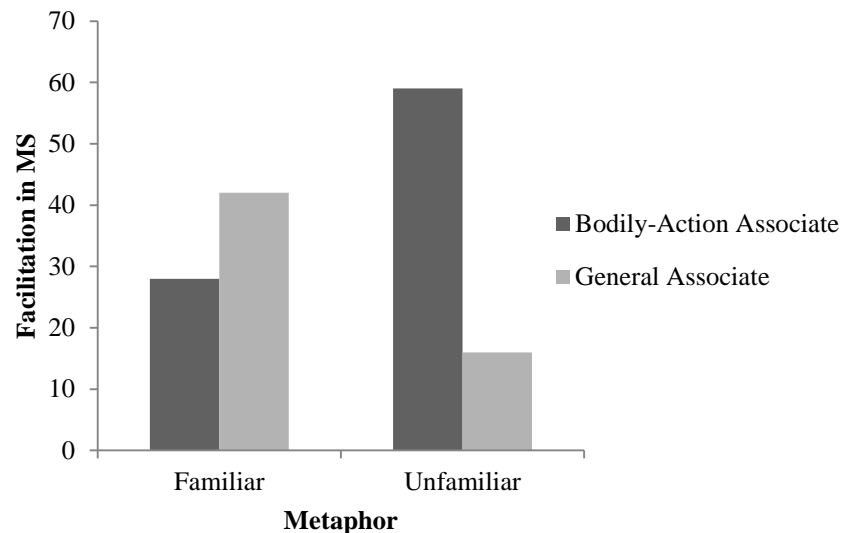


Figure 4. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar metaphors in Study 4.

To determine if conditions were significantly facilitated or suppressed, planned *t*-tests (two-tailed) were conducted to compare general and bodily-action associates to their respective control conditions. For familiar metaphors, only the general associates were significantly faster (by 42 ms) than their respective controls, $t(95) = 2.72$, $p = .008$, $d = .278$. For the unfamiliar metaphors, only the bodily-action associates were significantly faster than their respective controls, (by 59 ms), $t(95) = 3.32$, $p = .001$, $d = .339$. The 28 ms difference for the familiar metaphor bodily-action associates and their respective controls did not reach significance, $t(95) = 1.59$, $p = .115$, $d = .162$, neither did the 16 ms difference between the general associates and their respective controls for the unfamiliar metaphors, $t(95) = 1.00$, $p = .319$, $d = .102$.

Discussion

The main finding from this experiment is the three-way interaction. The locus of the interaction is an opposite pattern of effects among familiar and unfamiliar metaphors. In interpreting these results, I will first discuss the activation effects separately for each metaphor and then describe how the differential effects may be accounted for by the embodied and amodal models.

Familiar metaphors activated general properties of the vehicle, but not sensorimotor properties in the form of bodily-actions. However, the nonsignificant 28 ms activation effect for bodily-actions is likely not due to random factors, as this difference is still appreciably large. Rather, it is possible that the bodily-action associates were indeed activated, but began to attenuate by the time the visual target was presented. This is plausible upon consideration of Weiland, Bambini and Schumacher's (2015) study which demonstrated that literal representations of vehicles are accessed initially during metaphor processing. In their experiment, which was an atypical cross-modal design, involving visual primes and auditory targets, participants heard metaphors in a context (*These lobbyists are hyenas...*). A masked prime (presented for 67 ms duration) consisting of a literal property of the vehicle (e.g., *furry*) was visually presented 100 ms before the onset of the auditory-presented metaphor vehicle (e.g., *hyenas*). The presence of the masked prime (e.g. *furry*) reduced the N400 to the target (e.g., *hyenas*), suggesting

that initial semantic processing of metaphor vehicles involves a literal representation¹⁴. Therefore, the lack of significance regarding the activation of bodily-action associates should not suggest they were not accessible, as experiments employing sensitive measures found evidence of literal representations influencing metaphor processing.

Effects directly opposite of the familiar metaphors were observed in their unfamiliar counterparts. Bodily-action associates were available immediately after hearing the metaphor vehicle. On the other hand, general associates showed no significant activation effects (16 ms) suggesting that this type of information about the vehicle is unavailable immediately after hearing the metaphor. This is inconsistent with previous cross-modal lexical priming studies, which found facilitation of all associates of the vehicle during upstream time-courses (Blasko & Connine, 1993; Rubio-Fernandez, 2007).

Implications for Embodied Simulation

The obtained results provide only partial support for Gibbs' simulation model (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007). Recall that in this model, it is argued that the cognitive processing of metaphor involves simulating the bodily-actions that characterize the vehicle. Evidence for such an embodied simulation mechanism for unfamiliar metaphors is apparent by the activation effects for bodily-action associates. Therefore, embodied semantic information seems to be available immediately for

¹⁴ The N400 amplitude is inversely related to ease of processing, such that a reduction in N400 amplitude suggests ease of processing.

processing unfamiliar metaphors. General semantic information, on the other hand, is unavailable, making it plausible that unfamiliar metaphors begin their processing mostly from accessing bodily-actions. This finding of initial activation of embodied properties for unfamiliar metaphors is so far consistent with both Gibbs' simulation model and sensorimotor shedding theory.

Although embodied simulation seems to initially underlie the processing of unfamiliar metaphors, it seems to play at most, a marginal role for the familiar metaphors. That is, the familiar metaphors showed activation for the general associates, and little-to-no activation for the bodily-action associates. Therefore, at upstream time-courses, familiar metaphors seem to be processed by accessing an abstracted sense of the vehicle, rather than constructing an embodied simulation. This finding, so far, is inconsistent with Gibbs' simulation model, because accordingly, familiar metaphors should be processed by embodied simulation similar to unfamiliar metaphors. However, this finding regarding the familiar metaphors is consistent with sensorimotor shedding theory.

In sensorimotor shedding theory, stimulus familiarity affects the degree to which metaphors are processed by embodied simulation (Jamrozik et al., 2016). That is, conceptual representations are initially embodied, and after repeated use, become abstracted. The obtained results, at least for the upstream time-course of the current study, are in alignment with sensorimotor shedding. Unfamiliar metaphors are primarily understood by embodied simulation. As such, they only activate bodily-actions. Familiar

metaphors, on the other hand, are understood by abstraction. In this case, the familiar metaphors activate general properties more-so than bodily-actions. Therefore, the results thus far support the sensorimotor shedding theory more-so than Gibbs simulation model.

Implications for Amodal Models

The finding of familiar metaphors activating general properties is consistent with both structure-mapping and categorization models of metaphor processing. Recall that structure-mapping (more precisely, the career of metaphor addendum) holds that conventional vehicles can readily access the abstract properties necessary for metaphor comprehension (Wolff & Gentner, 2011). Moreover, in the categorization model, abstract properties are the only basis for metaphor comprehension and as such, their activation is expected and arguably necessary (Glucksberg, 2008). Therefore, for familiar metaphors, the availability of general associates immediately after vehicle offset does not adjudicate between these two models.

The effects observed for the unfamiliar metaphors do adjudicate between the structure-mapping and categorization models. Bodily-actions, which are related to the vehicle's literal sense, were available immediately after hearing the metaphor vehicle. Such results are partially consistent with structure-mapping theory, as familiarity determines which sense of the vehicle is activated. Accordingly, unfamiliar metaphors are processed by accessing relations from the vehicle's literal representation. Presumably, the bodily-actions for unfamiliar metaphors are activated at the upstream time-course because the literal representation of the vehicle is immediately accessible. However, the

results are inconsistent with the categorization model, which predicts a facilitation of only general, but not literal, properties. Therefore, the categorization model is unsupported by the obtained results for unfamiliar metaphors at the upstream time-course.

The obtained results, though consistent with theory (i.e., sensorimotor shedding and structure-mapping theories) are nonetheless surprising because previous work showed that semantic properties associated with the prime word, despite their irrelevance to the sentence context, are typically activated during upstream time-courses. For example, the word *bugs* in the sentence, *he found several spiders, roaches and other bugs in his room* initially activates the associate *spy* regardless of its irrelevance to the sentence meaning (Swinney, 1979). Moreover, this is also true for words categorically related to a metaphor vehicle, but unrelated to the metaphor meaning; for instance, in the metaphor *John is a cheetah*, *cat* is initially activated despite its irrelevance to the metaphoric meaning (Rubio-Fernandez, 2007). Therefore, the fact that activation was observed for only some of the associates of metaphor vehicles is surprising. There is no clear answer for this; however, the experimental context, where participants were encouraged to think about each metaphor's meaning as they heard the audio, may have biased them to anticipate particular associates depending on metaphor familiarity (i.e., anticipate literal associates when a metaphor seems unfamiliar and general associates when a metaphor seems familiar – consistent with sensorimotor shedding theory).

The obtained interaction suggests that different semantic information is

immediately available to metaphors depending on their familiarity. However, it is not clear if this access is epiphenomenal, or a critical component of processing the metaphor's meaning. To determine if the facilitation effects obtained are critical components of processing, the current experiment was replicated at a longer ISI duration. Rubio-Fernandez (2007) found some associates of the vehicle which were activated upstream (at a 0 ms ISI) become suppressed downstream, 1000 ms later. Moreover, Blasko and Connine (1993) found that even for most poor quality metaphors, words related to their metaphorical meaning were activated at an ISI of 750 ms (for apt metaphors, words related to their metaphorical meaning are activated at a 0 ms ISI). Therefore, as applied to the paradigm employed here, the meaning of the metaphor will already be partially realized by a 1000 ms ISI. Moreover, associates unrelated to the metaphor's meaning should be attenuated by this time. As such, if the current activation effects obtained upstream are related to processing the metaphor's meaning then they should remain downstream. Conversely, these effects may attenuate if they are unrelated to the metaphoric meaning. Lastly, the associates which were not activated upstream may become activated downstream if they are related to the metaphor's meaning.

Each of the models reviewed above leads to a unique prediction regarding downstream activation effects. Gibbs' simulation model suggests that both familiar and unfamiliar metaphors should prime bodily-actions and general properties. This is because embodied simulation is mandatory, but may occur alongside structure-mapping or categorization processes (Gibbs & Matlock, 2008). According to sensorimotor shedding,

only unfamiliar metaphors should prime bodily-actions whereas familiar metaphors should prime general properties. Furthermore, according to structure-mapping, both familiar and unfamiliar metaphors should prime general associates, but unfamiliar metaphors may prime additional literal properties, such as bodily-actions. Lastly, according to the categorization model, only general properties should be primed by both metaphor types. See Table 10 for a summary of these theoretical predictions.

Table 10. Summary of theories and the downstream semantic activation they predict for familiar and unfamiliar metaphors in Study 5.

	Simulation Model	Sensorimotor Shedding	Structure-Mapping	Categorization
Familiar Metaphors	activation of sensorimotor & general properties	activation of general properties only	activation of general properties	activation of general properties only
Unfamiliar Metaphors	activation of sensorimotor & general properties	activation of sensorimotor properties only	activation of general and literal (sensorimotor) properties	activation of general properties only

Study 5

Method

Participants

Sixty-Eight people participated for partial course-credit (as University of Western Ontario students taking a psychology course) or for monetary compensation (\$5).

Participants were native speakers of English.

Materials

The same materials as in Study 4 were used here.

Procedure

The same procedure was used as in Study 4, with the only exception being a 1000 ms ISI between the offset of the vehicle prime and the visual presentation of the target stimulus.

Results

Trials with incorrect responses (4.07% of total dataset) were flagged. Of the errors, 56.39% were to non-words. The remaining errors for word trials are broken down by condition in Table 11. Once again, error rates are not uniformly distributed across conditions with the greatest percentage of errors for familiar metaphors being for general-unrelated words whereas for unfamiliar metaphors it is for unrelated bodily-actions. Similar to Study 4, the highest percentages of errors are generally for the relatively slow

conditions, suggesting the absence of a speed-accuracy trade off. Means and standard deviations can be found in Table 12.

Table 11. Breakdown of errors by condition for Study 5.

	Unfamiliar Metaphors	Familiar Metaphors
Word Type		
Bodily-Action Related	0.75%	5.26%
Bodily-Action Unrelated	12.03%	2.26%
General Related	1.5%	2.26%
General Unrelated	3.01%	16.54%

Table 12. Mean reaction times and standard deviation by each condition for Study 5.

Metaphor	Target Word	Relatedness	M	SD
Familiar	General	Rel.	595	135
		Unrel.	642	176
	Bodily-Action	Rel.	608	160
		Unrel.	623	137
Unfamiliar	General	Rel.	606	187
		Unrel.	603	147
	Bodily-Action	Rel.	596	137
		Unrel.	663	186

After removing error trials, an additional 0.4% of correct word trials were removed from the analysis because RTs exceeded 2000 ms (no RTs were below 300 ms.). The remaining trials were analyzed in the same way as Study 4. Most of the effects obtained in Study 4 were replicated. Related target words ($M = 601$) were responded to faster than unrelated controls ($M = 633$); $F_1(1, 64) = 15.49, p < .001, \eta_p^2 = .195$; $F_2(1, 16) = 5.41, p = .034, \eta_p^2 = .253$. Relatedness did not interact with familiarity, $F_1(1, 64) = 0.0, p = .99, \eta_p^2 = 0.0$; $F_2(1, 16) = 0.0, p = .995, \eta_p^2 = 0.0$ or associate, $F_1(1, 64) = 1.44, p = .234, \eta_p^2 = 0.022$; $F_2(1, 16) = 0.522, p = .480, \eta_p^2 = 0.032$. As in Study 4, a main-effect of familiarity was nonsignificant, $F_1(1, 64) = 0.0, p = .998, \eta_p^2 = 0.0$; $F_2(1, 16) = 0.012, p = .914, \eta_p^2 = 0.001$, as was the main-effect of associate; $F_1(1, 64) = 1.448, p = .233, \eta_p^2 = 0.022$; $F_2(1, 16) = 0.578, p = .458, \eta_p^2 = 0.035$. However, a familiarity by associate interaction was again obtained, $F_1(1, 64) = 5.24, p = .025, \eta_p^2 = .076$, by subjects but not by items, $F_2(1, 16) = 1.318, p = .268, \eta_p^2 = 0.076$. Lastly, the critical three-way interaction of familiarity by associate by relatedness was again obtained, $F_1(1, 64) = 9.60, p = .003, \eta_p^2 = .13$; $F_2(1, 16) = 10.81, p = .005, \eta_p^2 = .403$.

As in Study 4, Bonferroni-adjusted t -tests revealed that, for familiar metaphors, only the general associates are responded to significantly faster than general controls $t(67) = 3.102, p = 0.003, d = .3762$ whereas for unfamiliar metaphors, only bodily-action associates are responded to significantly faster relative to controls, $t(67) = 3.536, p < .001, d = .4288$. See Figure 5 for a graph depicting the facilitation effects.

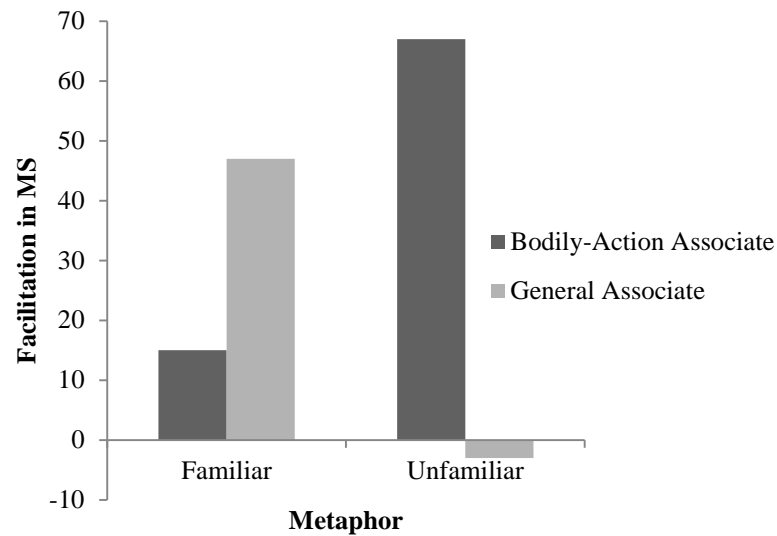


Figure 5. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar metaphors in Study 5.

Discussion

The same interaction found in Study 4 was replicated, which shows that the activation effects observed upstream remain downstream. Moreover, the lack of activation observed upstream continues downstream as well. Such results confirm that the activation observed previously, was not an epiphenomenon, but rather, a result of processing the metaphor's meaning. Recall that Rubio-Fernandez (2007) found that the associates of the vehicle which are unrelated to the metaphor's meaning are activated upstream but not downstream (i.e., after a 1000 ms ISI). Moreover, Blasko and Connine (1993) reported that words representative of a metaphor's meaning are immediately activated at a 0 ms ISI for apt metaphors and by 750 ms for inapt metaphors. Therefore,

the 1000 ms ISI used in the current study characterizes a time-course in processing where the metaphor's meaning is at least partially realized. As such, the bodily-actions and general properties appear to be key semantic properties for unfamiliar and familiar metaphors, respectively. Moreover, the fact that both metaphors types immediately activated such key semantic properties suggests that they are apt.

The current results can be interpreted similarly to those obtained in Study 4. In regards to embodied approaches of metaphor, the results are consistent with the sensorimotor shedding theory (Jamrozik et al., 2016). Accordingly, in processing unfamiliar metaphors, sensorimotor properties are drawn from the literal-sense of the vehicle. However, an abstracted sense of the vehicle develops with metaphor familiarity. As such, in processing familiar metaphors, sensorimotor properties are bypassed for more abstract properties that are directly accessed. Therefore, the current findings demonstrate that metaphors activate semantic properties in the way described by sensorimotor shedding theory. The results obtained here, like in Study 4, are inconsistent with Gibb's simulation model, in which it is argued that processing metaphors entails mandatory activation of sensorimotor properties of the vehicle (Gibbs & Matlock, 2008). Such mandatory sensorimotor processing appears to be present in unfamiliar metaphors, but not in familiar metaphors. Therefore, the central tenant of Gibb's simulation model is unsupported in by the data obtained in the current study.

With respect to the amodal models; namely, structure-mapping and categorization, the current results are not supportive of either. Recall that according to

both models, metaphor comprehension involves the access of figurative properties of the vehicle. Therefore, the activation of general properties during the processing of familiar metaphors is supportive of both structure-mapping and categorization. However, the activation effects obtained during the processing of unfamiliar metaphors do not support these models. In structure-mapping, the claim is made that processing unfamiliar metaphors involves extracting figurative properties from the literal-sense of the vehicle. Therefore, processing unfamiliar metaphors should activate general properties, and possibly, additional literal properties. This prediction was partially supported, as unfamiliar metaphors only activated literal properties (i.e., bodily-actions); however, the lack of activation for general properties is inconsistent with structure-mapping. Moreover, the activation of literal properties, in the form of bodily-actions, is inconsistent with the categorization model, where it is argued that metaphor processing involves inhibition of such properties.

In sum, the obtained effects are consistent with the sensorimotor shedding framework, where stimulus familiarity determines the degree of embodied processing of metaphor. Gibbs' simulation model was unsupported, because processing familiar metaphors did not activate sensorimotor properties in the form of bodily-action associates. Moreover, structure-mapping and the categorization model were unsupported because unfamiliar metaphors did not activate general properties.

One particular issue that needs to be addressed is the complete lack of activation for general associates of unfamiliar metaphor vehicles and bodily-action associates of

familiar metaphor vehicles. Although such null effects have been explained within theoretical frameworks, it is possible that the items used in the current studies were simply unable to result in priming effects. That is, the target words which were never primed at either ISI may have been too weakly associated to their respective primes. This is possible because the associates, on average, were weakly associated to the vehicles (.03-.08). This is especially worrisome considering the previous work in cross-modal lexical priming showing that all associates are initially activated when presented at the offset of the prime (Swinney, 1979; Rubio-Fernandez, 2007).

In order to rule-out the possibility that the null effects were due to weak associations, only vehicles will serve as auditory primes in Studies 6 and 7. In Study 6, the duration of the ISI was 0 ms whereas in Study 7 it was 1000 ms. For both studies, no three-way interactions are predicted. Rather, comparable priming effects should be observed in all conditions.

Study 6

Method

Participants

Sixty-five people participated for partial course-credit (as University of Western Ontario students taking a psychology course) or for monetary compensation (\$5). Participants were native speakers of English.

Materials

Only the vehicles were used as audio primes. This was achieved by trimming the audio file up to the onset of the vehicle. Pilot testing confirmed that the spoken audio was comprehensible¹⁵.

Procedure

The procedure was similar to the previous experiments, with the main difference being that the prime consisted of the vehicle alone. Moreover, participants were told to pay attention to the words they heard in the headphones, because doing so may help make the lexical decision easier.

Results

One subject's data was removed from analysis because they scored less than 85% correct in the lexical decision data. Trials with incorrect responses (5.5%) were flagged and removed from the main analysis. Of the errors, 61% were for non-words. The remaining errors can be seen by condition in Table 13 whereas means and standard deviations can be found Table 14.

¹⁵ This method of trimming audio can result in distorted speech, as a result of co-articulation. To ensure the words were comprehensible, an additional five participants were asked to listen to the audio and write-out the words they heard, after data for Study 6 and 7 was collected. For the experimental prime words, the accuracy across the five subjects was 99% (only one participant misreported a word). For the control prime words (non-word trials) the accuracy was 98% (two participants each misreported a different word). Furthermore, the vehicles were always the last words of the sentence; therefore, there is no preservative co-articulation (anticipation of an upcoming word).

Table 13. Breakdown of errors by condition for Study 6.

	Unfamiliar Vehicles	Familiar Vehicles
Word Type		
Bodily-Action Related	1.18%	2.96%
Bodily-Action Unrelated	11.24%	4.14%
General Related	2.96%	2.96%
General Unrelated	4.14%	9.47%

Table 14. Mean reaction times and standard deviations for each condition in Study 6.

Vehicle Prime	Target Word	Relatedness	M	SD
Familiar	General	Rel.	571	109
		Unrel.	615	149
	Bodily-Action	Rel.	555	108
		Unrel.	609	131
Unfamiliar	General	Rel.	548	88.6
		Unrel.	589	125
	Bodily-Action	Rel.	554	138
		Unrel.	648	130

Of correct word trials, 0.61% of the data was removed due to responses made after 2000 ms or below 300 ms. The remaining trials were analyzed in the same way as Study 4. A main-effect of relatedness was obtained, $F_1(1, 60) = 40.03, p < .001, \eta_p^2 = .40$; $F_2(1, 16) = 23.41, p < .001, \eta_p^2 = .594$, however relatedness did not interact with

associate $F_1(1, 60) = 2.7461, p = .103, \eta_p^2 = .044$; $F_2(1, 16) = 2.579, p = .128, \eta_p^2 = .139$ or familiarity $F_1(1, 60) = 1.7003, p = .197, \eta_p^2 = .028$; $F_2(1, 16) = 1.203, p = .289, \eta_p^2 = .070$. The main-effect of familiarity was nonsignificant, $F_1(1, 60) = .0901, p = .765, \eta_p^2 = .002$; $F_2(1, 16) = 0, p = .985, \eta_p^2 = 0.0$, as was the main-effect of associate $F_1(1, 60) = 1.603, p = .210, \eta_p^2 = .026$; $F_2(1, 16) = 0.794, p = .386, \eta_p^2 = 0.047$. However familiarity interacted with associate in the subject analysis $F_1(1, 60) = 7.83, p = .007, \eta_p^2 = .115$ but only marginally by items, $F_2(1, 16) = 3.28, p = .089, \eta_p^2 = .17$. Although Figure 6 may suggest a three-way interaction, it was nonsignificant, $F_1(1, 60) = 2.44, p = .123, \eta_p^2 = .039$; $F_2(1, 16) = 1.86, p = .192, \eta_p^2 = .104$ (The inclusion of list as a factor did not meaningfully change the p -value, suggesting this nonsignificant interaction was not due to excess variance in the error term). Therefore, the lack of facilitation effects in the previous experiments was not due to lack of associative strength. In summary, both types of associates were facilitated by at least 40 ms.

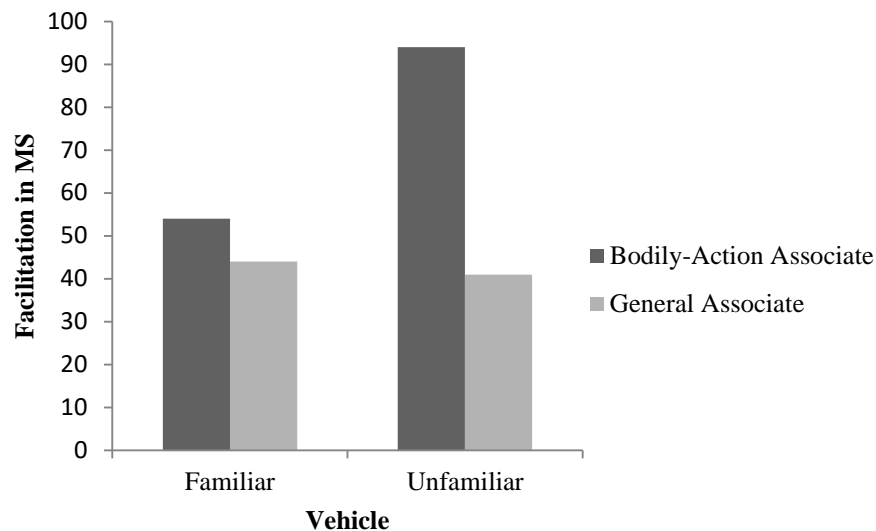


Figure 6. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar vehicles in Study 6.

Discussion

Study 6 confirms that the vehicles were capable of priming their respective targets. This suggests that the lack of activation observed in Studies 4 and 5 were due to top-down processes rather than associative weakness at the lexical level. One striking finding is the 94 ms priming effect for the unfamiliar vehicles and their bodily-action associates. Despite this, the interaction was nonsignificant. Furthermore, the sample size is similar to other studies of this nature, making it unlikely an interaction was not obtained due to lack of statistical power. Lastly, even if the interaction was significant, it would not rule-out the fact that the other targets were also primed. Therefore, the current results confirm the vehicles' respective associates were related enough to result in priming. In order to compare the downstream effects, Study 6 was replicated but with a

1000 ms ISI. The same priming effects observed in Study 6 are expected to remain downstream.

Study 7

Method

Participants

Sixty-four people participated for partial course credit (as University of Western Ontario students enrolled in a psychology course) or for monetary compensation (\$5).

Materials and Procedure

The same stimuli and procedure employed in Study 6 was used again, with the exception that now there was a 1000 ms ISI between the offset of the prime and the onset of the target.

Results

Trials with incorrect responses (3.48%) were flagged and removed from the main analysis. 56.07% of the errors were for non-words. Table 15 shows the breakdown of errors by condition and Table 16 shows the means and standard deviations for each condition.

Table 15. Percentage of errors by condition for Study 7.

	Unfamiliar Vehicles	Familiar Vehicles
Word Type		
Bodily-Action Related	1.87%	3.74%
Bodily-Action Unrelated	14.02%	7.48%
General Related	0%	1.87%
General Unrelated	3.74%	11.21%

Table 16. Mean reaction times and standard deviations for each condition in Study 7.

Vehicle Prime	Target Word	Relatedness	M	SD
Familiar	General	Rel.	571	108
		Unrel.	619	108
	Bodily-Action	Rel.	587	124
		Unrel.	626	132
Unfamiliar	General	Rel.	584	131
		Unrel.	592	128
	Bodily-Action	Rel.	580	94.6
		Unrel.	649	131

After removal of trials exceeding 2000 ms or below 300 ms (0.27% of correct word trials) the remaining trials were submitted to a two by two by two ANOVA. A main-effect of associate was obtained in the subject analysis, $F_1(1, 60) = 5.25, p = .026, \eta_p^2 = .08$, but not the item analysis, $F_2(1, 16) = 1.372, p = .259, \eta_p^2 = .079$; general

associates ($M = 591.5$) were responded to faster than bodily-action associates ($M = 610.5$). Moreover, the main-effect of familiarity was nonsignificant. $F_1(1, 60) = .0157, p = .901, \eta_p^2 = 0.0$; $F_2(1, 16) = 0.0, p = .997, \eta_p^2 = 0.0$. Furthermore, familiarity did not interact with associate; $F_1(1, 60) = .7851, p = .379, \eta_p^2 = 0.013$; $F_2(1, 16) = 0.5473, p = .470, \eta_p^2 = 0.033$. A main-effect of relatedness was obtained, $F_1(1, 60) = 39.83, p < .001, \eta_p^2 = .399$; $F_2(1, 16) = 17.88, p < .001, \eta_p^2 = .528$. However, relatedness did not interact with familiarity, $F_1(1, 60) = .1167, p = .734, \eta_p^2 = 0.002$; $F_2(1, 16) = 0.179, p = .895, \eta_p^2 = 0.001$, or associate, $F_1(1, 60) = 3.0767, p = .085, \eta_p^2 = 0.049$; $F_2(1, 16) = 1.9293, p = .184, \eta_p^2 = 0.108$. The three-way interaction was significant $F_1(1, 60) = 4.98, p = .029, \eta_p^2 = .077$; $F_2(1, 16) = 7.10, p = .017, \eta_p^2 = .307$. As Figure 7 shows, the interaction suggests that the vehicles from the unfamiliar metaphors do not prime general associates at the 1000 ms ISI. This suggests that the isolated vehicle of unfamiliar metaphors results in similar priming effects as the vehicle when used metaphorically.

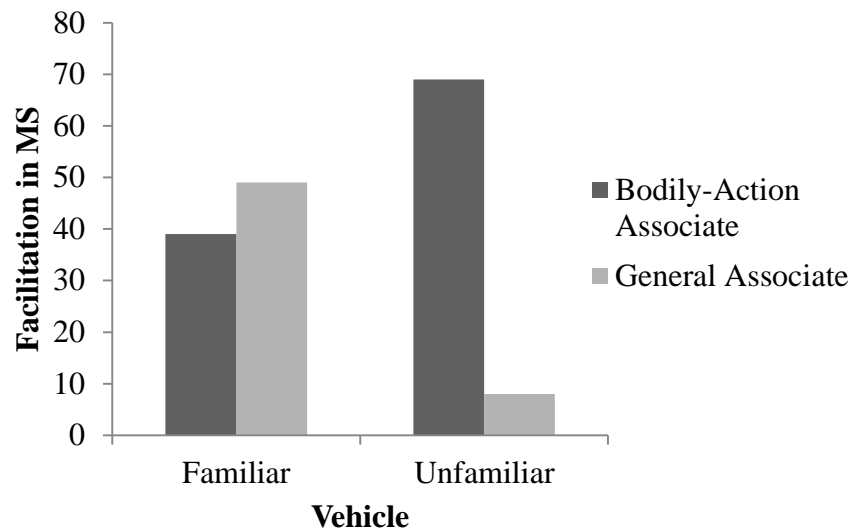


Figure 7. Facilitation of Bodily-Action and General Associates across Familiar and Unfamiliar vehicles in Study 7.

Discussion

The vehicles of unfamiliar metaphors did not prime general associates, but priming was observed in the other conditions. It seems that the upstream effect, in which unfamiliar vehicles prime general associates, completely decays downstream. Such complete decay was not observed in the other conditions. Taken together with the results of Study 6 (the 0 ms ISI), it seems that familiar and unfamiliar metaphor vehicles differ in the strength to which they are related to different types of information. Familiar metaphor vehicles seem to be equally associated in strength to both sensorimotor and general properties. On the other hand, unfamiliar metaphor vehicles, although related to both sensorimotor and general properties, maintain stronger links to the former than the

latter. Moreover, this implies that the lack of activation for general associates during the downstream processing of unfamiliar metaphors is due to decay rather than active inhibition or suppression.

On the basis of the similar forward-associative strengths for the primes and their targets, this interaction was not predicted. Instead, priming effects similar to Study 6 were expected. Nonetheless, although these effects were not predicted, they do in fact fit with the general career-of-metaphor hypothesis. The career of metaphor hypothesis describes how a concept develops a figurative sense (Bowdle & Gentner, 2005). Recall that in structure-mapping, metaphor comprehension is achieved by mapping shared structures of the topic and vehicle. For example, in a metaphor such as *some suburbs are parasites*, the matching process may identify the shared relation *exists in dependence of a host*. After such a mapping, relations unique to the vehicle, such as *harms its host* are projected to the topic (Wolff & Gentner, 2011). The career-of-metaphor hypothesis states that when a metaphor vehicle is used frequently, its abstracted meaning becomes lexicalized. That is, *parasites* readily refers to an abstraction because it is used frequently in metaphoric phrases. As such, the dictionary definition of *parasites*, obtained from Google, contains both the biological definition (i.e., “an organism that lives in or on another organism (its host) and benefits by deriving nutrients at the host’s expense”) along with the figurative definition (i.e., a person who habitually relies on or exploits others and gives nothing in return.). Moreover, sensorimotor shedding uses the career-of-metaphor framework as a foundation to describe how a concept’s embodied representation may become abstract

(Jamrozik et al., 2016). As such, conceptual representations are grounded in sensorimotor processes, but after repeated use in metaphoric contexts, develop stronger associations to an abstracted sense.

The results obtained in Study 7 provide support for this notion. The familiar vehicles, due to their frequent use in metaphor, can prime both associates related to a literal representation (i.e., bodily-actions) and associates related to an abstraction (i.e., general associates). Conversely, unfamiliar vehicles have yet developed strong links to their abstracted sense. Rather, they are still literal and primarily point to a literal representation when used in a metaphor. Although this reasoning is post-hoc, it is nonetheless consistent with sensorimotor shedding. These results suggest that vehicles for familiar and unfamiliar metaphors differ in their lexical representations. Familiar vehicles are associated with a literal and abstracted sense whereas unfamiliar vehicles are associated with a literal sense more-so than abstracted sense. As such, the familiar vehicles prime both associate types upstream and downstream. Unfamiliar vehicles on the other hand, only prime both associates upstream; downstream, the general properties lose their activation because the vehicle concept has yet to develop a figurative abstraction.

General Discussion

Unfamiliar metaphors activated sensorimotor, but not general, semantic properties of the vehicle whereas the opposite was found for familiar metaphors. This finding was observed in upstream (Study 4) and downstream (Study 5) time courses. In Study 6,

which served as a control experiment, it was found that the metaphor vehicles, irrespective of familiarity, activate both sensorimotor and general semantic properties during an upstream time course, thus ruling out the possibility that lack of activation observed in metaphoric contexts was due to weak associative strength between vehicles and their targets. In Study 7 it was found that the activation of general associates of unfamiliar vehicles decays downstream. Taken together, these findings suggest that unfamiliar metaphors are initially processed as embodied simulations whereas familiar metaphors are processed by amodal processes such as categorization. Moreover, the different overall pattern of results between the experiments employing vehicles in metaphor contexts (Studies 4 and 5) and those employing the vehicle in isolation (Studies 6 and 7) suggest that participants were processing the metaphors figuratively. That is, the different pattern of results confirms the metaphors were attended to, and that participants were not simply ignoring the metaphors and paying attention only to the vehicles. If one were only attending to the vehicles, Studies 6 and 7 would replicate the effects found in Studies 4 and 5, respectively.

The experiments reported in this chapter are the first to demonstrate online evidence of embodied simulation in nominal metaphor processing. As such, the findings suggest that unfamiliar metaphors activate sensorimotor properties online. This finding can shed light on the results of Study 3, in which the use of perceptual-embodied language in metaphor interpretations was detected in an offline task. Recall that those results raised questions regarding whether embodied representations are accessible online

or offline. The current results suggest that embodied representations were available to participants online when they created and interpreted novel metaphors in Study 3.

Therefore, the presence of perceptual-embodied language in the metaphor interpretations appears to be due to an embodied simulation where sensorimotor properties of the vehicle are immediately accessible for use in metaphor understanding.

The obtained results are relevant for characterizing online metaphor processing, along with adjudicating between psycholinguistic theories of metaphor comprehension. I will first compare and contrast the results with other metaphor studies that employed cross-modal priming tasks. Then I will describe how the obtained results can adjudicate between the classic amodal models, along with the more recent embodied models.

Implications for Online Metaphor Processing

To date, two other cross-modal priming studies, using auditory metaphors as primes and visual targets, have been carried out (but see Stewart & Heredia, 2002 and Weiland et al. 2014 for variations of this technique). An overview of those studies' results, along with the current study, can be found in Table 17. At the very least, the studies provide converging evidence that critical semantic information related to the metaphor is immediately available after hearing the vehicle. Moreover, immediately at the offset of the vehicle, for most metaphors, emergent properties related to the figurative meaning are already available. Unsurprisingly, other semantic information related to the vehicle, but unrelated to the metaphor, is also immediately available, likely as a result of

spreading activation. Such information includes the vehicle's literal properties (Blasko & Connine, 1993), its superordinate category name, and its distinctive features (Rubio-Fernandez, 2007). Some of this information, such as the vehicles' distinctive features, remains facilitated downstream. Other information, such as the vehicle's superordinate category, is no longer facilitated downstream, suggesting it is irrelevant for the metaphor's meaning. Depending on the familiarity of the metaphor, differing semantic information is also involved. For familiar metaphors, general properties of the vehicle are immediately available, and remain so downstream. Conversely, for unfamiliar metaphors, sensorimotor properties of the vehicle are immediately activated, and remain so downstream. Taken together, the current and previous studies show that online metaphor processing immediately activates a wide array of semantic information, and a subset of particular information related to the vehicle remains activated downstream, a finding consistent with theories of sentence comprehension (e.g., Gernsbacher et al. 2001; Kintsch, 2000).

Table 17. Overview of related cross-modal priming experiments and findings

Study	Metaphors	Targets	ISI (ms)	Findings
Blasko & Connine (1993)	Familiar & Unfamiliar; (Highly Apt/Moderately Apt) e.g., <i>Hard work is a ladder</i>	Metaphorical (e.g., <i>advance</i>) Literal (e.g., <i>rungs</i>) Control (e.g., <i>pastry</i>)	0, 300, 750	0 & 300 ms: Activation of metaphorical and literal targets for familiar and highly apt unfamiliar metaphors; Activation of literal targets for moderately apt unfamiliar metaphors 750 ms: Activation of metaphorical and literal targets for most moderately apt unfamiliar metaphors
Rubio-Fernandez (2007)	Unfamiliar e.g., <i>John was a cheetah</i>	Superordinate (e.g., <i>cat</i>) Distinctive Feature (e.g., <i>fast</i>) Unrelated Control (e.g., <i>sleep</i>)	0, 400, 1000	0 & 400 ms: activation of superordinate and distinctive feature targets 1000ms: activation of distinctive feature targets
Current Study	Familiar & Unfamiliar e.g., <i>Time is a snail</i>	General Associate/Control (e.g., <i>slow/afraid</i>) Bodily-Action Associate/Control (e.g., <i>crawl/rake</i>)	0, 1000	0 & 1000 ms: activation of general associative targets for familiar metaphors and bodily-action associative targets for unfamiliar metaphors

Implications for Amodal Theories of Metaphor Processing

Although the current study was carried out to determine if embodied representations are accessible during online metaphor processing, the results can nonetheless be interpreted within the classic psycholinguistics debate between Gentner versus Glucksberg (and their colleagues). This debate is centered on how the topic and vehicle interact to produce figurative meaning, and more precisely, the nature of the vehicle's representation. Recall that in Gentner's structure-mapping framework, the topic and vehicle representations are aligned and their shared similarities are identified (e.g., the alignment of *parasites* and *suburbs* result in the shared structure of *dependence on a host*). This alignment allows for the relations in the vehicle to be identified and then projected to the topic (i.e., *harms its host*). This process is the same mechanism underlying analogical comparisons. As such, the vehicle is thought to refer to a literal representation in which relations are extracted from. Moreover, familiarity can constrain how the structure-mapping process is carried out (i.e., the career of metaphor hypothesis; Bowdle & Gentner, 2005). For familiar metaphors, the structure-mapping process is particularly efficient because the vehicle readily points to relations (e.g., *parasite* is readily associated with *harms its host*). Conversely, for unfamiliar metaphors, the vehicle's abstraction must be computed from scratch (e.g., in a metaphor like *science is a glacier*, the vehicle does not readily point to an appropriate relation). In either case, the vehicle's relations are derived from a literal representation.

Alternative to structure-mapping is the categorization model (Glucksberg, 2008).

According to this model, the vehicle refers to an abstract category constructed ad-hoc for comprehending the metaphor (e.g., in *lawyers are sharks*, sharks refers to a category of predatory, vicious things and not a literal fish). As such, the constructed category contains properties which are attributed to the topic. Unlike structure-mapping, the categorization model treats unfamiliar and familiar metaphors as the same; in either case, the vehicle refers to an abstract category. However, according to this model, *aptness* is a requirement for constructing a metaphor category (i.e., the quality of metaphor hypothesis; Glucksberg & Haught, 2006). That is, for an inapt metaphor, the vehicle may not typify a category, and as such, will be processed literally where features, rather than relations, maybe attributed to the topic.

In the current study, the metaphors varied on familiarity, but were all considerably apt, making them prime items to test structure-mapping and categorization models. On the one hand, structure-mapping leads to the prediction that the familiar and unfamiliar metaphors should be processed differently. On the other hand, the categorization model leads to the opposite prediction that the familiar and unfamiliar metaphors, because they are both apt, should be processed the same. The obtained results, in which familiar and unfamiliar metaphors demonstrated different semantic activation effects, support the structure-mapping model more-so than the categorization model. Nonetheless, the structure-mapping model does not satisfactorily account for all the obtained effects. That is, though a difference in processing between the familiar and unfamiliar metaphors is consistent with structure-mapping, the fact that unfamiliar metaphors only activate

sensorimotor properties is inconsistent with the model. Therefore, both amodal models cannot meaningfully account for the obtained results in which sensorimotor properties play a critical role in the processing of unfamiliar metaphors.

Implications for Embodied Simulation

In Gibbs' and colleagues' embodied simulation framework, bodily-actions related to the metaphor are the basis of comprehension (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007). Previous research found support for this framework but was limited to verb-based metaphors, such as *swallow your pride* and *push the argument* (Wilson & Gibbs, 2007). Such metaphors are unambiguous in their reference to bodily-actions. However, nominal metaphors, such as *lawyers are sharks*, do not reference particular bodily-actions. Nonetheless, because the vehicle's referent is typically concrete, it is likely associated with bodily-actions. The current study is the first to investigate the role played by simulating bodily-actions during online metaphor processing, with results providing support for embodied simulation underlying unfamiliar, but not familiar, metaphors.

The activation of bodily-actions for unfamiliar metaphors indicates that such properties are accessible during online processing. Moreover, activation of bodily-action associates was observed both upstream and downstream, suggesting that such effects are not epiphenomenal. These findings are predicted by Gibbs' embodied simulation theory (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007). Conversely, bodily-actions were not

activated for familiar metaphors upstream or downstream, suggesting such semantic properties are not accessed during the processing of familiar metaphors. Such findings are inconsistent with Gibbs' embodied simulation theory, as bodily-actions are, accordingly, a critical source for constructing metaphorical understanding. As such, in Gibbs's simulation theory, the activation of sensorimotor properties is mandatory for metaphor comprehension. The fact that evidence of embodied simulation was only observed for unfamiliar metaphors is a problematic issue for this model, and others with a similar position on mandatory activation of sensorimotor properties during language processing (e.g., Lakoff, 2008; 2012).

Hybrid embodiment theories, on the other hand, can accommodate such findings where sensorimotor processing is ubiquitous, although not mandatory. For example, according to dual coding theory, metaphor comprehension is carried out by joint processing of the verbal and image systems (Paivio & Walsh, 1993). Within the framework of this study, both associate types are represented in the verbal system, which houses the entire lexicon. However, words can also be represented in the image system, depending on the extent to which they denote imageable phenomena. Therefore, the bodily-action associates are additionally represented in the image system because they are rich in motor imagery. The general associates, on the other hand, are more abstract than the bodily-actions and are therefore represented mostly in the verbal system alone. Therefore, the isolated activation of either sensorimotor or general properties is consistent with the functional architecture of DCT.

In processing unfamiliar metaphors, bodily-actions are activated; as such, both image and verbal systems are particularly involved. However, in processing familiar metaphors, general associates are activated and therefore only the verbal system is typically involved. However, although DCT can explain how the different associate types are represented, it is unclear why any given metaphor, based on its familiarity, would activate one associate over another. That is, DCT does not lead to any a priori predictions regarding when the image system is involved in metaphor processing. Therefore, DCT is partially supported because the data demonstrate qualitative differences of activation based on imagery. However, DCT in its current form fails to describe why metaphor familiarity affects the degree of activation of the image system.

Unlike DCT, in the sensorimotor shedding theory stimulus familiarity is specifically described to be the factor that results in the activation of either sensorimotor or amodal representations (Jamrozik, et al., 2016). In this framework, sensorimotor representations are necessary for processing unfamiliar metaphors, but are no longer necessary for familiar metaphors which are processed amodally. Accordingly, unfamiliar metaphors can only be processed by sensorimotor simulation of the vehicle. However, after frequent use, an abstraction of the vehicle becomes readily accessible and sensorimotor simulation is no longer necessary. The current findings, where unfamiliar metaphors activate bodily-actions and familiar metaphors activate general properties, fit with such a framework.

Sensorimotor shedding is a general framework, not only to describe metaphor

processing, but also the gradual abstraction of concepts (Jamrozik, et al., 2016).

Accordingly, concrete concepts are represented primarily by sensorimotor representations. However, concepts develop abstract senses when they are frequently used metaphorically. For example, a concept such as *muscle* primarily refers to a literal representation grounded in sensorimotor properties. However, as *muscle* is frequently used metaphorically, (e.g., *negotiation is a muscle*, *concentration is a muscle*, *reading is a muscle*, etc.), its sensorimotor representation attenuates and an abstracted sense, such as, *something that improves with practice*, becomes part of the conceptual representation (Jamrozik et al., 2016).

Further support for sensorimotor shedding comes from Studies 6 and 7, where the auditory prime consisted of the isolated vehicle. Recall that in Study 6, which characterized upstream processing, vehicles primed both the general and bodily-action associates. However, in Study 7, which characterized downstream processing, the vehicles of familiar metaphors primed both associate types, but the vehicles from unfamiliar metaphors only primed bodily-action associates. According to sensorimotor shedding, the vehicles from the familiar metaphors have developed strong links to an abstracted sense. As such, the familiar vehicles prime both associate types upstream and downstream. Unfamiliar vehicles on the other hand, only prime both associates upstream; downstream, the general properties lose their activation because the vehicle concept has yet to develop strong connections to its abstracted sense. Although the results of Study 6 and 7 were not predicted, they are nonetheless consistent with sensorimotor shedding.

Conclusions

The experiments reported herein show that during processing, unfamiliar metaphors activate sensorimotor properties whereas familiar metaphors activate amodal properties. Such results cannot be accounted for models that stress mandatory activation of sensorimotor properties (e.g., Gibbs & Matlock, 2008) nor models that stress inhibition of such properties (Glucksberg, 2008). Rather, they are consistent with sensorimotor shedding theory (Jamrozik et al., 2016) in which sensorimotor and amodal processes are argued to underlie unfamiliar and familiar metaphors respectively.

Chapter 5

General Discussion

The novel findings of this dissertation will be summarized, and their impact on theories of metaphor processing will be reviewed. In Chapter 2, participants rated artificially generated metaphors, which varied on vehicle-BOI, for comprehensibility. Metaphors containing low-BOI vehicles were rated as more comprehensible than those containing high-BOI vehicles. In addition, participants rated low-BOI metaphors as more comprehensible when the vehicle's semantic neighbourhood is sparse (i.e., low-SND) rather than dense (i.e., high-SND). In Chapter 3, participants were presented with abstract words, and chose vehicles to create metaphors. Participants chose low-BOI vehicles more than high-BOI vehicles to create metaphors, thus conceptually replicating the low-BOI effects obtained in the comprehensibility studies of Chapter 2. Furthermore, to create metaphors, participants preferred to choose low-BOI vehicles when they were from sparse semantic neighbourhoods rather than from dense semantic neighbourhoods, also conceptually replicating the BOI by SND interaction obtained in Chapter 2. Lastly, the preference for low BOI – low SND vehicles was higher when the topic of the metaphor was high-SND rather than low-SND. Thus, participants consistently chose vehicles with poorer rather than richer semantic representations, especially when the topic itself had a rich semantic representation. Taken together, these findings support the semantic richness hypothesis of metaphor, which is based on SND effects (Al-Azary & Buchanan, 2017),

and demonstrate it generalizes to another richness variable, namely BOI.

The BOI and SND effects summarized thus far do not adjudicate between the amodal approaches to metaphor, which dominate the psycholinguistics literature, and the embodied approaches, which, though theoretically intriguing, lack empirical support. In Chapter 3 this gap was addressed by asking participants to verbally interpret the metaphors they had created. The verbal interpretations were assessed to the degree they contained perceptual-embodied language (i.e., words related to perception, motion, or the body). Irrespective of vehicle-BOI level, metaphor interpretations contained, on average, the same amount of perceptual-embodied language. This finding aligns with the predictions of embodied approaches of metaphor, which argue for such ubiquitous effects (Jamrozik et al., 2016; Gibbs & Matlock, 2008; Paivio & Walsh, 1993). In Chapter 4, a cross-modal lexical priming paradigm was used to determine if embodied representations are accessible during online processing. The results showed that unfamiliar metaphors activated bodily-actions related to the literal sense of the vehicle. Familiar metaphors, on the other hand, activated general properties related to the abstract sense of the vehicle. Such results are supportive of hybrid models that consider both amodal and embodied representations to be involved in metaphor processing (Jamrozik, et al., 2016; Paivio & Walsh, 1993). Below I will outline how the obtained results align with specific amodal and embodied approaches to metaphor. The obtained semantic richness effects in metaphor will then be discussed.

Amodal Models

Recall that in amodal models of metaphor it is assumed that the topic and vehicle's semantic representations are not tied to sensorimotor properties. The data obtained in this dissertation provide evidence against this assumption. Therefore, amodal models would need to be adjusted in order to account for the embodied effects obtained. Below I will suggest how amodal models might be reconciled with the obtained data to encompass a role for sensorimotor properties in metaphor comprehension. Each specific model will be discussed in turn.

Categorization Model

In the categorization model, it is argued that the literal representation of the vehicle is inhibited; instead, metaphors only reference the vehicle's abstract representation (Glucksberg, 2008). This assumption does not align with the obtained results in which sensorimotor properties (which are related to the literal representation of the vehicle) were accessed. For example, in the metaphor interpretation results Chapter 3 (Study 3), participants oftentimes described the vehicle in literal terms. For example, the metaphor *luck is a butterfly* was interpreted in part by considering how literal butterflies are hard to capture, much like luck is hard to find. Moreover, the interpretations on average contained a significant amount of perceptual-embodied language, which further indicates participants were accessing concrete representations and not only abstractions, contrary to the categorization model's assumption.

The findings from the cross modal lexical priming studies (Chapter 4, Study 4 and

5) are also problematic for the categorization model. Recall that during upstream and downstream time-courses, unfamiliar metaphors activated bodily-actions associated to the literal representation of the vehicle, but did not activate properties associated to its abstracted representation. This finding is inconsistent with the categorization model because accordingly, unfamiliar metaphors should be understood by accessing the abstracted sense of the vehicle. Conversely, familiar metaphors showed activation of general properties and non-activation of bodily-actions. This particular finding is consistent with the categorization model – accordingly, to understand such metaphors, an ad-hoc category made-up of abstract properties is constructed.

In sum, the majority of the effects obtained in this dissertation are inconsistent with the categorization model, where it is argued that the literal representation of the vehicle is inhibited in the processing of apt metaphors. One cannot argue the effects obtained in this thesis that do not support this model are due to the use of inapt metaphors. Evidently, the metaphors employed in the studies in Chapters 3 and 4 are apt. For instance, the participants in Chapter 3 interpreted metaphors that they created themselves and as such, those metaphors likely were apt from their perspective. Moreover, the unfamiliar metaphors used in Chapter 4 (Studies 4 and 5), although rated to be less apt than the familiar metaphors, are still sufficiently apt (recall that the mean aptness ratings for the familiar and unfamiliar metaphors are 7.06 and 5.02, respectively). Furthermore, their aptness ratings were obtained from a norming study in which participants rated the metaphors when they were presented in isolation rather than a

linguistic context (e.g., Roncero & Almeida, 2015). However, in Studies 4 and 5, the metaphors were placed in a linguistic context (e.g., *the vet likes to remind her clients that pets are kids*), likely increasing their aptness. In fact, hearing the unfamiliar metaphors in context immediately activated critical semantic properties, which is a feature of apt metaphors (Blasko & Connine, 1993). Therefore, the effects in Chapter 3 and 4 cannot be attributed to the use of poor quality metaphors.

Although the categorization model has been influential, the limited support for it in the current study raises questions about the future it has in metaphor processing research. One issue is that proponents of the categorization view argue that the literal representation contains properties unrelated to the metaphor, and this is why an ad-hoc category is necessary. However, as shown in Study 3, metaphor interpretations included imagery related to the literal sense of vehicle. Moreover, unfamiliar metaphors primed bodily-actions related to the literal sense of the vehicle in Studies 4 and 5. Therefore, in its current form, the categorization model cannot address the obtained data and I would argue, for continued viability, the categorization model must be re-articulated to consider the role of imagery.

Another issue with the categorization model is that it does not include topic concreteness in its framework. The majority of the stimuli employed in studies that support the categorization model are concrete metaphors (such as *lawyers are sharks*) when, in fact, metaphors often have abstract topics. Indeed, recall that in Study 1, people rated abstract metaphors as more comprehensible than concrete metaphors. Moreover, it

is not clear how an abstract metaphor can be processed in terms of a categorization mechanism. That is, in natural categorization, the category is more abstract than its members (e.g., *fruit* is more abstract than *apple*; Rosch, 1978). To illustrate how this mechanism is problematic for the processing of abstract metaphors, consider an abstract metaphor such as *secrecy is a rat*. According to the categorization model, the vehicle *rat* exemplifies an abstract category that is constructed ad-hoc in which the topic, *secrecy*, is included as a member. However, it is not clear how an ad-hoc category can be constructed for the inclusion of an abstract concept, because the category must be more abstract than the topic (e.g., the ad-hoc category exemplified by *rat* must be more abstract than the highly abstract word *secrecy*). Therefore, the categorization model in its current form can only account for the processing of familiar metaphors made up of concrete topics.

In conclusion, the categorization model has been influential in the psycholinguistics of metaphor literature, but it is difficult to see how it can lead to new predictions and explanations without some major revisions to its functional architecture. Moreover, if categorization is amended to include literal representations of the vehicle, then it will begin to resemble its rival theory, structure-mapping.

Structure-Mapping

Unlike the categorization model, in the structure-mapping framework (Gentner & Bowdle, 2008), figurative relations are drawn from the literal representation of the

vehicle. That is, although this model does not place emphasis on sensorimotor properties, its architecture does not preclude the potential access of sensorimotor representations. As such, the general structure-mapping framework can be made consistent with moderate views of embodiment (Wolff & Gentner, 2011). Nonetheless, in the structure-mapping theory of metaphor, a specific role for sensorimotor representations is not articulated. Rather, the focus is on how relations of the vehicle are computed, and, as currently formulated, this computation ignores imagery or simulation processes. Overall then, structure-mapping theory does not predict, *a priori*, perceptual-embodied language in metaphor interpretations, such as those observed in Chapter 3. However, such results do not undermine the theory's central tenants.

Recall that the structure-mapping theory has the career-of-metaphor addendum, which states that, as metaphors become more familiar, their processing involves readily accessing abstractions from the vehicle (Bowdle & Gentner, 2005). This property of the theory was partially supported in Chapter 4, where familiar metaphors activated associates related to the vehicle's abstraction whereas unfamiliar metaphors activated bodily-actions related to the vehicle's literal sense. This is only partial evidence however, because, the bodily-action associates remained active at the downstream time-course (i.e., 1 second) which is inconsistent with the theory. Recall that Rubio-Fernandez (2007) showed that properties irrelevant to metaphor lose activation downstream. Therefore, the fact that the activation of sensorimotor properties remained downstream is inconsistent with structure-mapping theory. Overall then it appears the theory can be extended to

accommodate the empirical evidence presented in this thesis confirming the role of sensorimotor representations in metaphor, though still has difficulty with downstream activation of sensorimotor properties. Perhaps a revised model of structure-mapping can be created that stresses that imagery is drawn from the vehicle, alongside figurative relations, in forming metaphor interpretations.

Structure-mapping has been extended to many important domains of metaphor and figurative processing, namely, how figurative processing develops in children (Gentner, 1988), how metaphor relates to other similarity processes such as analogy (e.g., Gentner, Bowdle, Wolff & Boronat, 2001); the time course of metaphor processing (Wolff & Gentner, 2000; 2011); how metaphoric meanings become conventional abstractions (Bowdle & Gentner, 2005) and importantly, has been implemented in a computational model (Falkenhainer, Forbus, & Gentner, 1989). Given structure-mapping's already impressive contributions to theories of metaphor, and its empirical support spanning over three decades, it is difficult to envision future metaphor comprehension theories without structure-mapping involved in some way.

Predication Model

In the predication model (Kintsch, 2008) properties underlying metaphor comprehension are drawn from semantic neighbourhoods, which are made-up of words that co-occur with the topic and vehicle. Recall the predication model does not make general predictions regarding the semantic content of metaphor interpretations or whether

sensorimotor properties (though represented amodally) are activated or not. Rather, the model computes a vector which represents a metaphor's meaning in semantic space. Its accuracy can be determined by assessing the proximity of the metaphor vector to other vectors representing properties one expects to be related to the metaphor (Kintsch, 2000), or the proximity of the metaphor vector to a vector representing human interpretations of the metaphor (Kintsch & Bowles, 2002). Whether or not the metaphor vector contains sensorimotor properties depends on whether such properties are related to the topic and vehicle.

The predication model bases its computations on semantic representations determined by LSA. Therefore, the efficacy of the predication model in computing metaphor meanings partly rests on how well LSA models semantic memory. Recall that LSA is a co-occurrence model. As such, it does not include any direct sensorimotor experiences that may shape semantic memory (Landauer, Foltz & Laham, 1998); sensorimotor content is only indirectly captured by LSA to the extent that it is verbally coded in natural language (Landauer, Foltz & Laham, 1998). This raises the question of whether or not LSA contains enough sensorimotor properties to model the embodied simulation and mental imagery involved in novel metaphor understanding, such as in the interpretations generated by participants in Chapter 3.

Consider the embodied interpretation of the metaphor *amusement is a butterfly* provided by a participant: “*Have you watched a butterfly flutter from flower to flower? In the sunshine and the tall grass and wildflowers, that is truly amusing*”. Most of the key

properties in this interpretation are not, according to LSA, in the semantic neighbourhood of *butterfly*. For example, according to LSA, in the 1500 nearest neighbours of *butterfly*, *sunshine*, *grass*, *wildflowers*, *flutter*, or *flower* are not included (although *crabgrass* is included). On the other hand, for most of the unfamiliar metaphors in Chapter 4, the bodily-action associates were among the vehicle's 1500 nearest neighbours. Therefore, it seems that LSA may lack the perceptual information from the physical world in order to construct mental imagery necessary for higher-order metaphor interpretations.

The issue of co-occurrence models lacking perceptual information has been recently addressed. Durda, Buchanan and Caron (2009) demonstrated that semantic features of words (obtained by McRae, Cree, Seidenberg & McNorgan, 2005) can be mapped onto co-occurrence vectors. Therefore, human-generated features of *butterfly*, such as *flies*, *has wings*, *is colourful*, and *pollinates flowers* (McRae et al., 2005) can be mapped onto the co-occurrence vector computed for *butterfly*. To that end, Durda et al. (2009) trained a feed-forward neural network to associate features to appropriate co-occurrence vectors. After training, the model was able to correctly map features from concepts it was trained on to semantically related concepts that it was not trained on. This study thus supports the notion that co-occurrence models can be grounded with additional perceptual information that is not readily available in discourse, but available from human participants. Moreover, Durda et al.'s (2009) method, in principle, can be applied to other semantic variables such as BOI wherein a co-occurrence model can be trained to learn BOI values of concepts. One can then see whether this information is generated to

novel concepts related to the training items. Overall then, it is likely that, the predication algorithm could in principle generate metaphor vectors that contain adequate sensorimotor properties if LSA is bolstered with perceptual-embodied variables such as semantic features and BOI.

Embodied Models

The obtained results described in the studies reported in this thesis are generally supportive of embodied models of metaphor processing. However, as I will review below, the embodied models differ in their ability to accommodate the data obtained in the online experiments (Chapter 4). As such, I argue that the data favours some models more than others.

Gibbs Simulation Model

In Gibbs' (Gibbs & Matlock, 2008; Wilson & Gibbs, 2007) model of metaphor processing, comprehension is necessitated by sensorimotor simulations evoked by the vehicle, with particular emphasis on bodily-actions. Therefore, a strong prediction that arises from this model is that perceptual-embodied language will be present in metaphor interpretations. This prediction was confirmed, even with the nominal metaphors generated and interpreted as described in Chapter 3. These data suggest that during metaphor understanding participants engage in an embodied simulation in which dynamic sensorimotor properties related to the vehicle shape their understanding of the topic. Importantly, in the simulation model, it is argued that embodied simulations are a

requirement for understanding metaphors. The data presented here support this claim: both high-BOI and low-BOI metaphors resulted in interpretations with similar levels of perceptual-embodied language. This finding is supportive of Gibbs' model because it demonstrates the robustness of simulation. That is, the data show that people engage in simulations even when the vehicle concept is low-BOI, and hence difficult with which to interact.

Recall that the metaphors studied in Chapter 3 were relatively novel as they were created by participants from a list of presented words and hence not obviously based on dead metaphors or pre-existing live familiar metaphors. In Chapter 4 (Studies 4 and 5), familiar and unfamiliar (i.e., novel) metaphors were employed in an online processing task. In support of Gibbs' model, processing unfamiliar metaphors (e.g., *time is snail*) resulted in immediate activation of bodily-actions related to the vehicle (e.g., *crawl*) at both upstream and downstream time-courses. Activation of such bodily-actions is expected if an embodied simulation is required to understand metaphor. However, Gibbs' model predicts that familiar metaphors also are understood by embodied simulation processes; however, this was not observed. Familiar metaphors (e.g., *lawyers are sharks*) did not activate bodily-actions (i.e., *bite*) at upstream or downstream time-courses, suggesting that such metaphors are not understood as embodied simulations, a finding inconsistent with Gibbs' model. Rather, processing familiar metaphors activated general associates (e.g., *killer*) not directly related to an embodied simulation. Gibbs and Matlock (2008) argued that psycholinguistic evidence (up to 2008) disagrees with the idea that

“people access...figurative meanings by simply accessing a pre-established sense from a mental lexicon without engaging in any imaginative bodily activities (pg. 174)”.

However, as previously mentioned, the experiments in this dissertation are the first to test embodied simulation of nominal metaphors, and the evidence here shows that familiar metaphors are indeed understood by accessing a particular sense of the vehicle without consideration of relevant bodily-actions.

In sum, the findings from the studies conducted in this thesis partially support Gibbs’ model, as evidence for embodied simulation was found for novel metaphors in both offline and online tasks. It should be noted that Gibbs’ model is partly based on observations where seemingly dead metaphors, such as *swallow your pride* are understood by bodily simulation (Wilson & Gibbs, 2007). According to this model, if dead metaphors are processed as embodied simulations, so should familiar metaphors. However, recall that nominal metaphors, such as *lawyers are sharks*, do not denote bodily-actions. As such, these metaphors do not overtly draw attention to bodily-actions, unlike metaphors like *swallow your pride*. Therefore, nominal metaphors may automatically activate sensorimotor representations, but this activation attenuates when the metaphor becomes familiar and a path to an abstracted sense of the vehicle becomes immediately available (as described in the sensorimotor shedding theory; Jamrozik et al., 2016). Overall then, Gibbs’ model cannot be reconciled with the data regarding the familiar metaphors in Chapter 4, where bodily-actions were not activated upstream or downstream, and general associates were immediately available. Finally it should be

noted that if Gibbs' model is amended to include amodal processing for familiar metaphors, it will be indistinguishable from the sensorimotor shedding theory, discussed previously.

Dual Coding Theory

Dual coding theory (DCT, e.g., Paivio, 1971; 2007) is a general theory of mental representation and processing, and only incidentally extended to the study of metaphor. The central tenant of dual coding theory as applied to metaphor extends its basic argument that, processing involves joint contributions of both amodal (i.e., verbal) and multimodal (i.e., imagery) representations. As such, one should find evidence for both non-sensory and sensory (imagistic) knowledge in the processing of metaphors. This position is supported by both the metaphor interpretation data (Chapter 3) and the online processing experiments (Chapter 4). In Chapter 3, the average metaphor interpretations contained multimodal descriptions including visual, motoric, and auditory properties. Such descriptions are consistent with DCT, as the imagery system stores multimodal properties. Moreover, the imagery in the interpretations often described an entire scene rather than the vehicle concept in isolation. This is consistent with how metaphor related imagery is described in DCT. That is, the image system stores continuous images that are analogues to the perceptual word, rather than discrete units. Conversely, some interpretations excluded mention of perceptual-embodied language. This finding is also consistent with DCT, as metaphor understanding can be achieved solely within the verbal (i.e., amodal) system. In sum, the wide variety of metaphor interpretations, with some

including multimodal content and others not, aligns with DCT.

Despite the offline evidence, the data obtained in the cross-modal lexical priming experiments do not completely align with DCT. On the one hand, both general (i.e., amodal) and sensorimotor (i.e., imageable) properties were activated during online metaphor processing, in support of DCT. On the other hand, the activation of amodal or sensorimotor associated information depended on metaphor familiarity. This particular finding is not predicted by DCT, although it does not threaten the theory's central tenant. Moreover, the current version of the dual coding theory of metaphor (Paivio & Walsh, 1993) may be underspecified. In fact, since its latest instalment, variables such as metaphor familiarity (Bowdle & Gentner, 2005; Blasko & Connine, 1993), aptness (Blasko & Connine, 1993; Glucksberg & Haught, 2006) and others have been demonstrated to affect metaphor processing. Therefore, although DCT remains an attractive position regarding general cognition, it lacks specificity in describing how variables other than verbal associations and imagery affect metaphor processing. Nonetheless, DCT possess the functional architecture to be reconciled with variables such as familiarity. Overall then, after considering the results of Chapter 3 (i.e., metaphor interpretation task) and 4 (i.e., cross-modal lexical priming tasks) it is difficult to imagine a complete model of metaphor processing that does not consider the joint contribution of amodal and sensorimotor representations, as has been argued in DCT for decades.

Sensorimotor Shedding Theory

In sensorimotor shedding theory, the degree to which processing is amodal or embodied depends on metaphor familiarity (Jamrozik et al., 2016). Novel metaphors are processed by embodied simulation whereas conventional metaphors, on the other hand, are processed by accessing amodal representations. As such, this is the only theoretical framework that is consistent with both the metaphor interpretation data obtained offline (Chapter 3) and the pattern of priming results obtained online (Chapter 4). Recall that the metaphors that were interpreted in Chapter 3 were relatively novel. Therefore, the use of perceptual-embodied language in the metaphor interpretations, as indeed observed, is predicted by sensorimotor shedding. Moreover, Studies 4 and 5 (Chapter 4) provided additional evidence for sensorimotor shedding's position on metaphor familiarity. During online metaphor processing, different properties were activated depending on metaphor familiarity. That is, unfamiliar metaphors activated bodily-actions (i.e., sensorimotor properties) of the vehicle but not its general (i.e., abstract) properties, whereas familiar metaphors showed the opposite pattern of results.

Further support for sensorimotor shedding theory comes from Studies 6 and 7 (Chapter 4), where the auditory prime consisted of the isolated vehicle. Recall that isolated vehicles primed both the general and bodily-action associates at the upstream time-course. However, during downstream processing, the vehicles from familiar metaphors primed both associate types, whereas the vehicles from unfamiliar metaphors only primed bodily-action associates. According to sensorimotor shedding theory, the

vehicles from the familiar metaphors have developed an abstracted sense and therefore prime both associate types upstream and downstream. Unfamiliar vehicles on the other hand, only prime both associates upstream; downstream, the more abstract properties lose their activation because the vehicle concept has yet to develop strong associations to an abstraction.

One can envision further tests of sensorimotor shedding theory. For instance, a demonstration of sensorimotor shedding can be achieved by a method known as *in vitro conventionalization*. In this approach, introduced by Bowdle and Gentner (2005) and replicated by Thibodeau and Durgin (2011), participants are provided with figurative sentences (e.g., *hard work is like a ladder*, *education is like a ladder*) and are then asked to complete a sentence frame by choosing a new topic that is consistent with the figurative meaning of the sentences (i.e., _____ *is like a ladder*). This method is thought to rapidly conventionalize metaphors. This method could be applied to the unfamiliar metaphors used in Chapter 4 (e.g., *time is a snail*). Prior to the conventionalization process, I would predict a replication of Studies 4 and 5. That is, pre-conventionalization, metaphors should prime bodily-actions (e.g., *crawl*) but not the more abstract properties (e.g., *slow*), thus replicating the results obtained. However, a change in the type of activation should occur as a result of metaphor conventionalization. Therefore, post-conventionalization, metaphors should activate abstract properties more than bodily-actions. This method would permit an experimental test of whether novel metaphor vehicles indeed activate sensorimotor representations, and after they become

conventional, develop abstracted senses.

Overall, sensorimotor shedding leads to predictions that are confirmed by the data reported in Chapters 3 and 4. This theory is also consistent with recent neuroimaging work. Desai, Binder, Conant, Mano and Seidenberg (2011) asked participants to read literal (e.g., *the daughter grasped the flowers*), metaphoric (e.g., *the jury grasped the concept*) and abstract (e.g., *the jury understood the concept*) sentences in a brain-scanner. Their results showed numerous areas of activation, but critically, that literal and metaphoric sentences resulted in similar activation of sensorimotor areas that overlapped with performing hand actions. Moreover, activation of such areas is *negatively* correlated with stimulus familiarity; the less familiar the metaphor, the more activation is observed in the sensorimotor area. Furthermore, in another study, Desai, Conant, Binder, Park and Seidenberg (2013) conceptually replicated these findings. Like Desai et al., (2011), they studied literal, metaphorical, and abstract sentences, but also included idiomatic sentences (e.g., *the congress is grasping at straws in the crisis*), which are even more conventional than metaphors. They found a linear trend such that the strongest activation of a secondary motor area is observed during the reading of literal action-sentences, whereas minimal activation is observed during reading of idioms, the most conventional sentence type. Thus, words such as *grasp*, when used literally activate sensorimotor areas; however, the activation gradually attenuates during processing conventional senses of the same word (e.g., *grasp the concept*; *grasp at straws*). Therefore, two neuroimaging

studies provide converging evidence of sensorimotor shedding as a result of stimulus familiarity, complementing the results obtained in Chapter 4.

Semantic Richness

Recall that the conclusions from Chapter 2 (i.e., comprehensibility rating tasks; Studies 1 and 2) indicated that BOI and SND showed parallel and sometimes interactive effects on the comprehensibility of artificial metaphors. That is, metaphors with vehicles with low-BOI and low-SND values were rated as the most comprehensible. Moreover, in the vehicle selection task (Chapter 3), vehicles with low-BOI and low-SND values were among the most chosen to create novel metaphors. The predictions in Chapter 2 and 3 were that BOI, as a proxy for embodied simulation would show effects quite different than those found for SND, which is based on amodal representational units. However, the data I obtained showed that, contrary to predictions, BOI was not an appropriate variable to invite varying degrees of embodied simulation in metaphor processing tasks. Rather, in Chapter 3, high and low-BOI metaphors both resulted in interpretations including perceptual-embodied language. Moreover, the observed BOI and SND interactions were not predicted by the theoretical accounts reviewed. However, to the extent that BOI is an embodied variable, and SND an amodal variable, the obtained interactions support hybrid accounts (e.g., Jamrozik et al., 2016; Paivio & Walsh, 1993) that embrace both amodal and embodied representations. Given these findings the conclusion drawn was that both BOI and SND reflected an underlying semantic richness. I attempt below to consider how the semantic richness effects in metaphor processing tasks (including both BOI and SND)

might be explained in terms of computational processes.

The converging evidence from the experiments presented in this thesis and elsewhere (e.g., Al-Azary & Buchanan, 2017), is that semantic richness (beyond the concreteness of the vehicle) is detrimental to metaphor processing, for instance by making the item less comprehensible. I speculate that there are two main reasons for this, which are related. The first has to do with the total amount of semantic properties associated with a concept. Accordingly, semantically rich concepts, whether defined by SND or BOI, refer to more properties (i.e., associates and imagery, respectively) than semantically poorer concepts (e.g., low-SND words; low-BOI words). This can be an issue for processing metaphoric meaning, because only *some* of the vehicle's semantic properties are relevant for understanding a metaphor (e.g., Black, 1962). Therefore, when the vehicle of a metaphor is high-SND for example, a large network of close associates must be searched to determine metaphor-relevant properties. The same can be said if a vehicle is high-BOI; it will not only refer to visual imagery, but also to additional motor and perhaps tactile, olfactory or other forms of sensory imagery. When such semantically rich concepts are encountered in a metaphor processing task, cognitive control mechanisms must determine the relevant properties for the metaphor. If there are many properties, it is arguably more difficult to find the relevant comparisons than when there are few properties from which to choose. The remaining unrelated properties arguably, are then inhibited (e.g., Kintsch, 2000) or suppressed (e.g., Gernsbacher, et al., 2001). In sum, the argument is that, less semantic information can be more effective for metaphor

processing because a less exhaustive search can be carried-out, and less subsequent inhibition of unrelated properties is required.

The second reason that semantic richness might be detrimental for metaphor processing is related to what follows from a concept having a rich semantic representation. For instance, a particular consequence of semantic richness (defined by SND, BOI, or otherwise) is that the conceptual representation is “better-specified” (Pexman, Siakaluk & Yap, 2013, pg. 1). I speculate that the degree of semantic specification limits accessibility to the taking on of new meaning, a hallmark of metaphor. For example, consider a high-SND word that has many near neighbours which consequently, constrain its meaning. This neighbourhood would be too dense to accommodate new semantic associations, necessary for novel metaphor comprehension (see Al-Azary & Buchanan, 2017 for more elaboration). A low-SND concept, on the other hand, has fewer near neighbour and as such, has more ‘room’ in the space to form novel semantic associations. Therefore, in this regard, low-SND concepts are more semantically malleable than high-SND concepts. I speculate that, as with high-SND concepts a similar effect holds for BOI in which high-BOI words have a rich semantic representation, which specifies their meaning further¹⁶, constraining the degree of malleability. For example, a high-BOI concept’s semantic representation is well-specified for particular motor interactions, which can be resistant to novel semantic change. In

¹⁶ Thanks to Nick Reid for the thought-provoking suggestion that high-BOI concepts are so semantically specified.

similar ways, high-SND and high-BOI concepts are not as semantically malleable as their less-specified counterparts (i.e., low SND and low BOI). Thus, the detrimental effects of BOI on metaphor processing are similar to the previously reported detrimental effects of SND (Al-Azary & Buchanan, 2017).

To illustrate how a well-specified semantic representation can be inflexible for novel associations, consider the classic phenomenon of functional fixedness from the problem solving literature. When functional fixedness occurs, one has difficulty using an object for a new purpose other than that for which it most commonly used. For example, when an object is presented in a functionally specified way (e.g., a box holding objects) rather than a functionally unspecified way (e.g., an empty box) one may fail to use the object for a new use (e.g., using the box as a platform), despite the object's efficacy for the new use (Duncker, 1945). I speculate that a similar phenomenon occurs with semantically rich concepts. They are less likely to be used in a conceptually novel way (i.e., in a metaphor) because their semantic representation is more 'fixed'. My hypothesis regarding the degree of malleability as a function of the degree of semantic richness is empirically testable. For example, consider a concept's number of semantic features (McRae, et al., 2005), number of associates (Nelson et al., 2004) or number of meanings (Hino & Lupker, 1996). The hypothesis is that metaphors with topics and vehicles based on a low number of features, associates or senses will be more comprehensible than those with a high number of the respective variables. Moreover, vehicle frequency may also play a role, with less-frequent vehicles resulting in more comprehensibility than more-

frequent vehicles. Therefore, variables associated with a word's meaningfulness may provide converging results in metaphor comprehension tasks, such that less defined semantic representations are more conducive to metaphor processing. Paradoxically, a metaphor's meaningfulness is inversely related to its constituents' meaningfulness.

Conclusions

In this dissertation I tested psycholinguistic models of metaphor processing that assume embodiment. I found evidence that sensorimotor representations partially underlie semantic processing of metaphor. This evidence is contrary to the dominant experimentalist position that assumes only amodal processing of metaphor. The total evidence from offline and online experiments favours hybrid models that include amodal and embodied processing of metaphor. Moreover, novel findings regarding semantic richness were found. Interactive effects of BOI and SND showed that vehicles made-up of less-specified semantic representations facilitate metaphor comprehension and production, thus extending recent findings on the topic. In sum, the findings of this dissertation are the first to demonstrate sensorimotor activation in nominal metaphors using traditional psycholinguistic tasks, along with further characterizing detrimental effects semantic richness of metaphors.

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Appendices

Appendix A. Stimuli used in Study 1.

Abstract High-BOI	Abstract Low-BOI	Concrete High-BOI	Concrete Low-BOI
Shelter is Popcorn	Fervour is a Robot	A Woodpecker is an Umbrella	A Coach is an Eagle
Mastery is a Paper	Depth is a Pillar	A Broom is a Needle	A Scarecrow is a Pirate
Joy is a Shovel	Elevation is a Grasshopper	A Pool is a Table	Gear is a Panda
Imagination is a Vacuum	Discovery is a Kangaroo	A Bug is an Orange	A Shell is a Chimney
Daydream is a Slipper	Infusion is a Fountain	Coin is a Balloon	Roots is a Closet
Departure is a Band-Aid	Conduction is a Windmill	A Coast is a Razor	A Cover is a Genie
Digestion is a Puzzle	Art is a Hippo	A Motor is a Tweezers	A Wallet is a Donkey
Acclaim is a Paperclip	Elegance is Lightning	Shelf is a Wallet	A Tooth is a Giraffe
Turbulence is a Pencil	Arrival is a Turtle	A Trunk is a Lawnmower	A Tube is a Cowboy
Digestion is Lipstick	Exercise is a Rainbow	A Mirror is an Apple	A Politician is a Pillar
Cohesion is a Wheelchair	Censorship is a Fireman	A Sanctuary is a Toaster	An Armchair is Music
Cuisine is a Yo-Yo	Destiny is a Fire	Veins are Glasses	An Egg is a Rooster
Indecision is a Hammer	Diplomacy is a Pelican	A Sign is Handcuffs	Darkness is an Alligator
Confusion is a Stroller	Absorption is a Policeman	Star is a Teapot	A Sidewalk is a Waiter
Hesitancy is a Scissors	Advantage is a Desert	A Pond is a Helmet	Candy is a Parrot

Appendix B. Stimuli used in Study 2 (Replace Love with Time and Life for the other conditions).

High BOI - High SND	High BOI - Low SND	Low BOI - High SND	Low BOI - Low SND
Love is a bathtub	Love is a wheelchair	Love is a camel	Love is a kangaroo
Love is an earring	Love is a toilet	Love is a zebra	Love is an anvil
Love is pliers	Love is a slipper	Love is a statue	Love is a tiger
Love is a towel	Love is a band-aid	Love is a butterfly	Love is a cowboy
Love is a flashlight	Love is a balloon	Love is a rocket	Love is a peacock
Love is a backpack	Love is a teapot	Love is a leopard	Love is a alligator
Love is a typewriter	Love is a tweezers	Love is a dragon	Love is an eagle
Love is a pillow	Love is a yo-yo	Love is a gorilla	Love is a chimney
Love is a toothbrush	Love is a paper clip	Love is a dolphin	Love is a genie
Love is a telephone	Love is popcorn	Love is an elephant	Love is a music
Love is a football	Love is lipstick	Love is a mountain	Love is a pillar
Love is a skateboard	Love is a wheelbarrow	Love is a lizard	Love is a giraffe
Love is a ruler	Love is hammer	Love is a porcupine	Love is an igloo
Love is a necklace	Love is umbrella	Love is a castle	Love is a desert
Love is a motorcycle	Love is a paper	Love is a monkey	Love is a hippo
Love is a finger	Love is a helmet	Love is a submarine	Love is a rooster
Love is a cigarette	Love is a puzzle	Love is a dinosaur	Love is a lighthouse
Love is a spatula	Love is scissors	Love is a skeleton	Love is a raccoon
Love is a bicycle	Love is a shovel	Love is a cannon	Love is a pelican
Love is a trumpet	Love is a pencil	Love is a scorpion	Love is a unicorn
Love is a guitar	Love is a stroller	Love is a squirrel	Love is a panda
Love is a jacket	Love is a hammock	Love is a beaver	Love is a pyramid
Love is a camera	Love is a vacuum	Love is a walrus	Love is a donkey
Love is a banjo	Love is a hamburger		Love is a pirate
Love is a sweater	Love is an apple		Love is an eskimo
Love is a baby	Love is a screwdriver		Love is a fire
Love is a bottle	Love is a thermos		Love is a windmill
Love is a pitcher			Love is a city
Love is an envelope			Love is a lion
Love is a saxophone			Love is a llama
Love is a piano			Love is an octopus
Love is a violin			Love is an ostrich
			Love is a penguin
			Love is a rainbow
			Love is a volcano
			Love is a lightning

Appendix C. Stimuli used for Study 3

Topics:

High SND	Low SND
eternity	luck
euphoria	legacy
courage	revenge
loyalty	irony
repentance	prestige
honesty	destiny
epiphany	imagination
serenity	betrayal
empathy	nostalgia
patience	temptation
obsession	innocence
ambition	persuasion
sadness	metaphor
narcissism	miracle
guilt	boredom
sincerity	secrecy
hatred	solitude
cowardice	amusement

Vehicles:

High BOI High SND	High BOI Low SND	Low BOI High SND	Low BOI Low SND
typewriter	shovel	butterfly	lighthouse
flashlight	umbrella	submarine	volcano
violin	balloon	statue	pillar
pillow	wheelchair	medal	tiger
ant	pencil	anchor	pendulum
bicycle	puzzle	airplane	rainbow
cigarette	rat	cannon	palace
seed	clay	dinosaur	eagle
wine	hammer	rocket	lightning
sword	vacuum	castle	prairie
camera	gate	storm	cloud
fish	cat	mountain	desert

Appendix D. Stimuli used in Studies 4 – 7

Unfamiliar Metaphors and Targets:

Topic-Vehicle	Bodily Action	Bodily Action Control	General	General Control
Highways-Snakes	slither	gnash	danger	sugar
Health-Glass	break	nap	fragile	eager
Christ-Door	open	take	way	pride
Hearts-Closets	hide	wrap	dark	sweet
Time-Snail	crawl	rake	slow	afraid
Jobs-Jails	lock	chew	bad	icy
Eyelids-Curtains	close	slip	shade	skill
Peace-River	swim	dance	flow	coach
Sermons-Sleeping Pills	swallow	mingle	medicine	marketplace
Pets-Kids	play	kicks	love	house
Money-Oxygen	breathe	vomit	life	staff
Bible-Sword	fight	leap	weapon	wallpaper

Familiar Metaphors and Targets:

Topic-Vehicle	Bodily Action	Bodily Action Control	General	General Control
Alcohol-Crutch	limp	sigh	aid	cow
Winter-Death	bury	twist	dread	hustle
Wisdom-Ocean	surf	curl	deep	sorry
Love-Rose	smell	pray	beauty	spoon
Education-Stairway	climb	worry	up	quart
Life-Beach	swim	stand	fun	phone
Knowledge-Money	spend	digest	rich	special
Music-Medicine	taste	flick	cure	clergy
Insults-Daggers	stab	cough	weapon	spotlight
Memory-Sponge	wash	grip	absorb	convert
Minds-Computers	type	race	data	plant
Lawyers-Sharks	bite	enter	killer	jeans

Appendix E Metaphors in contexts for Studies 4 and 5.

Topic-Vehicle	Context
Highways-Snakes	My dad reminded me to drive slow and stay alert because HIGHWAYS ARE SNAKES.
Health-Glass	The doctor explained to the patient that HEALTH IS GLASS.
Christ-Door	At the gospel reading, Fred was reminded that CHRIST IS A DOOR.
Hearts-Closets	Some people don't like to talk about their emotions because for them, HEARTS ARE CLOSETS.
Time-Snail	Sometimes at work, my colleague says that TIME IS A SNAIL.
Jobs-Jails	Some people who work long hours believe that JOBS ARE JAILS.
Bible-Sword	For those who need strength in their faith, THE BIBLE IS A SWORD
Peace-River	During his meditation lessons, Elijah learned that PEACE IS A RIVER.
Sermons-Sleeping Pills	During the Sunday morning mass, the young children demonstrated that SERMONS ARE SLEEPING PILLS.
Pets-Kids	The vet likes to remind her new clients that PETS ARE KIDS.
Money-Oxygen	The investment banker believes that MONEY IS OXYGEN.
Eyelids-Curtains	When she has trouble falling asleep, Anna's mom tells her to pretend that her EYELIDS ARE CURTAINS.
Alcohol-Crutch	Lisa's friends were concerned about her drinking and tried to convince her that ALCOHOL IS A CRUTCH.
Winter-Death	For those who like sun and warmth, WINTER IS DEATH.
Wisdom-Ocean	The most important lesson that the professor ever taught her students was that WISDOM IS AN OCEAN.
Love-Rose	In the wedding vows, the bride said that LOVE IS A ROSE.
Education-Stairway	My academic counsellor told me that EDUCATION IS A STAIRWAY.
Life-Beach	My friend told me that I shouldn't stress because LIFE IS A BEACH.
Knowledge-Money	The valedictorian began her speech by saying KNOWLEDGE IS MONEY'.
Music-Medicine	People sometimes like to say that MUSIC IS MEDICINE.
Insults-Daggers	During the argument, Anthony realized that INSULTS ARE DAGGERS.
Memory-Sponge	Philosophers once believed that MEMORY IS A SPONGE.
Minds-Computers	When she watched him do complex math in his head, she realized that MINDS ARE COMPUTERS.
Lawyers-Sharks	Everyone in the courtroom agreed that those LAWYERS ARE SHARKS.

Curriculum Vitae

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